Energy, Mines and Resources Canada

Énergie, Mines et Ressources Canada

CANMET

Canada Centre for Mineral and Energy Technology

Centre canadien de la technologie des minéraux et de l'énergie

Mining Research Laboratories

Laboratoires de recherche minière

Canada

STRENGTH DETERMINATIONS OF KIDD CREEK MINE NO. 3 ROCKS

B. Gorski

MRL 90-097(TR)

DATE: Sept. 1990

Client: Falconbridge Limited

74 pp

MICROMEDIA

STRENGTH DETERMINATIONS OF KIDD CREEK MINE NO. 3 ROCKS

by

B. Gorski*

ABSTRACT

Laboratory tests were conducted on drill cores originating from diamond drilling activity at Kidd Creek Mine No. 3. The results of strength and deformation properties of the test specimens are presented in this report.

---

*Rock Mechanics & Development Technologist, Canadian Mine Technology Laboratory
Mining Research Laboratories, CANMET, Energy, Mines and Resources Canada, Ottawa, Canada

91-00383/

DÉTERMINATION DE LA RÉSISTANCE DE ROCHES PROVENANT DE LA MINE n° 3 DE KIDD CREEK

par

B. Gorski*

RÉSUMÉ

On a effectué des essais en laboratoire sur des carottes obtenues au cours d'opérations de forage à la mine n° 3 de Kidd Creek. On présente dans ce rapport les résultats relatifs à la résistance et aux propriétés de déformation des spécimens d'essai.

* Technicien de mécanique des roches et du développement, Laboratoire canadien de technologie minière, Laboratoires de recherche minière, CANMET, Énergie, Mines et Ressources Canada, Ottawa, Canada.

TABLE OF CONTENTS

		Page
	ABSTRACT	i
	RÉSUMÉ	ii
1.0	INTRODUCTION	1
2.0	TEST PROCEDURE	1
	SPECIMEN SELECTION	1
	SPECIMEN PREPARATION	1
	BRAZILIAN TEST	2
	CONVENTIONAL UNIAXIAL TEST	2
	MULTI-STAGE TRIAXIAL TEST	2
	DATA ACQUISITION/REDUCTION	2
3.0	TEST RESULTS	3
	TENSILE STRENGTH	3
	UNIAXIAL COMPRESSIVE STRENGTH	3
	ELASTIC CONSTANTS	3
	TRIAXIAL COMPRESSIVE STRENGTH	3
	HOEK AND BROWN M AND S MATERIAL CONSTANTS	4
4.0	OBSERVATIONS	4
5.0	REFERENCES	5

TABLES

No.		
1.	Specimen selection data	6
2.	Brazilian tensile strength	8
3.	Uniaxial compressive test results	9
4.	Multi-stage triaxial test results	10
5.	Geological Classification	12
6.	Hoek and Brown m and s material constants	13

FIGURES

No.

Fig. 1 Specimens 1 - 8B 14
Fig. 2 Specimens 11 - 20A 15
Fig. 3 Specimens 21 - 25 16
Fig. 4 Specimens 26 - 33 17
Fig. 5 Specimens 34 - 41 18

APPENDICES

A Stress-strain curves of uniaxial tests using strain gauges 19
B Stress-strain curves of triaxial tests using LVDTs 31

1. INTRODUCTION

MRL received from Falconbridge Limited, drill core samples originating from Kidd Creek Mine No. 3. An MTS 815 Rock Mechanics Test System was used to conduct uniaxial and multi-stage triaxial tests, and an ELE compression press to conduct Brazilian tensile tests. Triaxial tests were conducted using computer control on the MTS servo-hydraulic test system. The results of strength and deformation property tests are presented in this report.

2. TEST PROCEDURE

SPECIMEN SELECTION

Triaxial, uniaxial and brazilian tests were conducted on rock specimens cut from the received core. Specimens have been identified according to the sampling number given the core at the mine site. Additional specimens obtained from the same core stick have been designated alphabetically, for example;

Example 3A

3 - Mine sample number

A - additional sample from same core stick

The specimen location, test type, dimensions and density, δ, of each tested specimen, are listed in Table 1.

SPECIMEN PREPARATION

Rock core sample specimens selected for uniaxial and triaxial tests were prepared with length to diameter ratios ranging from 2:1 to 2.5:1. Brazilian tensile strength specimens were prepared with length to diameter ratios of 1:2. All specimens were lapped to within specified MRL tolerances, oven dried, weighed and dimensioned. Prior to testing, planes of discontinuity, if any, or potential weaknesses were highlighted with ink. Specimen preparation was performed according to the procedures used at MRL [1,2].

BRAZILIAN TEST

Test specimens were loaded to failure using a 2000 kN ELE compression press. The test procedure conformed to ISRM suggested methods [4].

CONVENTIONAL UNIAXIAL TEST

Test specimens were loaded to failure uniaxially at a rate of 0.75 MPa/s.

MULTI - STAGE TRIAXIAL TEST

The specimen was brought to equilibrium, under load control mode, by the simultaneous application of axial load and confining pressure, at the rate of 0.75 MPa/s. After the desired confining pressure of the first stage was reached, axial loading continued, at the rate of 0.75 MPa/s while the confining pressure was kept constant. When the axial load was 60 kN greater than the equilibrium load, the axial load was then reduced by 20%. The control mode was then switched over to axial displacement control. The test was continued, at an axial displacement rate corresponding to an axial stress rate of 0.75 MPa/s until initial failure occurred, as detected by an axial load drop. The axial displacement was then stopped and reduced by 33% of total axial displacement.

The desired confining pressure of the second stage was then applied and loading continued according to the same method just outlined for the first stage. The procedure was subsequently repeated for each predetermined increment of confining pressure. Confining pressures of 30, 40, 50, 60, 70, 80, 90 and 100 MPa were used.

The confining pressure of the last stage was held through the peak strength until the residual strength was visually established, as indicated by a plateau in the stress/strain curve recorded by the X-Y recorder. The specimen was then further axially displaced an additional 0.5 mm, while the confining pressure was linearly reduced to zero within a time period of 60 seconds. This last phase of the test was required for residual strength data. Residual strength data was determined for 3 specimens of each rock type tested.

DATA ACQUISITION/REDUCTION

Uniaxial and triaxial data were scanned and stored digitally on hard disk using a PDP 11/73 computer every 3 seconds. Analog signals from the load cell, circumferential extensometer, axial LVDTs, and confinement pressure were scanned. Real time plots of load versus axial displacement were obtained using a HP7046B X Y1 Y2 pen recorder wired to a MTS 448.85 controller.

The raw signals were reduced to engineering units and stored on hard disk for later recall. Measurements from axial LVDTs were corrected for end platen compression in the sensing gauge length. Reduced data were transferred to a VAX 750 computer for specimen material constant determinations. Hard copy plots of triaxial test results for report purposes were obtained using the DEC LVP16 pen plotter. A laser printer was used to provide hard copy plots of uniaxial test results. The DEC LA50 printer was used to provide hard copies of reduced triaxial data for analyses.

3. TEST RESULTS

TENSILE STRENGTH

Tensile strength, σ_t, results obtained by Brazilian test, are listed in Table 2.

UNIAXIAL COMPRESSIVE STRENGTH

The peak strain values, ϵ_{peak}, listed in Table 3, were determined by readings from the axial strain gauges. The uniaxial compressive strength results, Q_u, are also listed in Table 3.

Appendix A provides stress-strain plots using signals from axial strain gauges and circumferential strain gauges mounted on specimen surfaces.

ELASTIC CONSTANTS

The modulus of elasticity, E, (calculated at 0.5 Q_u), and the Poisson's ratio, ν, were established in each uniaxial compressive test case using load cell, and strain gauge data. The obtained results are listed in Table 3.

TRIAXIAL COMPRESSIVE STRENGTH

The triaxial compressive strengths of the selected specimens were determined at successive confining stages of: 30, 40, 50, 60, 70, 80, 90 and 100 MPa.

The stress-strain curve plots of the multi-stage triaxial tests are found in Appendix B. Axial strain measurements were made using LVDT units.

The results of the multi-stage tests are tabulated in Table 4.

HOEK AND BROWN M AND S MATERIAL CONSTANTS

Triaxial, uniaxial and Brazilian test results were used in the Hoek and Brown failure criteria to determine the failure envelope for each rock type. Table 6 contains the derived material constants, m and s. Figures 1 to 5 depict the Mohr circle plots for each of the rock types. The method of analyses is limited to triaxial strengths that exceed $3.4\sigma_3$. Accordingly, results from confinement pressures above 40 MPa were excluded in analyses of the talc - carbonate rock.

4. OBSERVATIONS

The geological classification of different rock core units are listed in Table 5. For each rock type tested, triaxial strengths increased with increasing specimen density and decreased with the prescence of existing planes of weakness. With the exception of the strong Andesite, the specimens exhibited brittle to ductile transition at the higher confinement pressures to varying degrees.

5. REFERENCES

1. Gorski, B. "The design and operation of a stiff triaxial assembly for post-failure rock property testing"; *Division Report MRP/MRL*82 – 81(*TR*); CANMET, Energy, Mines and Resources Canada; 1982.

2. Gyenge, M. and Herget, G. "Pit slope Manual 3-2; Laboratory tests for design parameters"; *CANMET Report* 77 – 26; CANMET, Energy, Mines and Resources Canada; 1977.

3. Gorski, B. "A multi-use load system for rock testing";*Division Report M&ET/MRL*86–, 25(*TR*); CANMET, Energy, Mines and Resources Canada; 1986.

4. Brown, E.T. "Rock characterization testing and monitoring"; *ISRM*; *Pergamon Press, London, England*; 211p; 1981.

Table 1 Specimen Selection Data

Sample Number	Depth (m)	Test Type	Length (cm)	Diameter (cm)	Density (Mg/m^3)
1	403.4	Uniaxial	9.130	3.625	2.77
1A	403.4	Triaxial	9.0)	3.631	2.71
2A	405.2	Triaxial	8.923	3.633	2.80
3	405.2	Triaxial	8.758	3.639	2.80
3A	405.2	Triaxial	9.025	3.634	2.82
3B	405.2	Triaxial	9.169	3.633	2.77
4	405.2	Triaxial	9.370	3.635	2.70
5	408.5	Triaxial	9.071	3.635	2.73
5A	408.5	Triaxial	8.900	3.636	2.72
6	408.5	Triaxial	9.032	3.633	2.72
6A	408.5	Triaxial	8.465	3.636	2.73
7A	408.5	Brazilian	1.870	3.633	—
7B	408.5	Brazilian	1.790	3.633	—
7C	408.5	Brazilian	1.892	3.633	—
8A	410.8	Brazilian	1.997	3.633	—
8B	410.8	Brazilian	2.005	3.633	—
11	423.0	Triaxial	7.737	3.637	3.82
12	423.0	Triaxial	7.154	3.633	4.14
12A	423.0	Brazilian	1.962	3.635	—
13	424.5	Triaxial	7.080	3.635	4.04
14	424.5	Triaxial	7.661	3.634	3.78
14A	424.5	Brazilian	2.032	3.634	—
14B	424.5	Brazilian	1.865	3.634	—
15	425.3	Triaxial	7.494	3.638	4.00
15A	425.3	Triaxial	7.207	3.640	3.99
16	425.3	Triaxial	7.376	3.637	3.97
17	443.6	Triaxial	7.312	3.639	3.60
18	443.6	Triaxial	7.196	3.630	3.71
18A	443.6	Brazilian	1.642	3.629	—
19	529.6	Triaxial	7.211	3.638	2.89
20	529.6	Uniaxial	6.959	3.636	2.98
20A	529.6	Brazilian	1.947	3.634	—

Table 1 Specimen Selection Data (cont'd)

Sample Number	Depth (m)	Test Type	Length (cm)	Diameter (cm)	Density (Mg/m^3)
21	273.8	Triaxial	10.973	4.671	2.84
22	273.8	Triaxial	9.131	4.666	2.85
24	275.0	Triaxial	11.267	4.663	2.83
25	275.0	Triaxial	11.453	4.666	2.76
26	486.9	Triaxial	11.766	4.678	2.98
26A	486.9	Brazilian	2.317	4.673	—
27	494.2	Triaxial	11.665	4.710	3.01
28	494.2	Triaxial	11.596	4.701	3.05
29	494.2	Triaxial	11.630	4.702	3.07
29A	494.2	Uniaxial	10.164	4.703	3.05
30	616.2	Triaxial	11.630	4.698	3.03
30A	616.2	Brazilian	2.775	4.693	—
30B	616.2	Brazilian	2.717	4.694	—
31	793.3	Triaxial	11.604	4.645	3.19
32A	793.3	Brazilian	2.383	4.744	—
32B	793.3	Brazilian	2.299	4.745	—
32C	793.3	Brazilian	2.550	4.744	—
33	793.3	Uniaxial	13.565	4.747	3.04
34	979.6	Triaxial	11.400	4.710	2.84
34A	979.6	Triaxial	11.183	4.711	2.83
35	979.6	Triaxial	11.260	4.702	2.83
36	979.9	Triaxial	9.381	4.708	2.84
36A	979.9	Triaxial	8.948	4.710	2.85
37	979.9	Triaxial	9.192	4.711	2.86
37A	979.9	Brazilian	2.324	4.720	—
38	982.9	Uniaxial	9.046	4.694	3.33
39	982.9	Triaxial	9.505	4.704	2.84
39A	982.9	Triaxial	8.910	4.709	2.83
39B	982.9	Brazilian	2.388	4.714	—
40	983.2	Triaxial	11.306	4.714	2.83
40A	983.2	Brazilian	2.404	4.708	—
41	983.2	Triaxial	8.699	4.703	2.84

Table 2 Brazilian Tensile Strength

Sample Number	Depth (m)	Failure Load (kN)	σ_t (MPa)
7A	408.5	9.70	9.09
7B	408.5	7.78	7.62
7C	408.5	16.84	15.60
8A	410.8	15.64	13.72
8B	410.8	18.72	16.36
mean		13.73	12.48
std. dev.		±4.74	±3.92
12A	423.0	4.62	4.13
14A	424.5	14.77	12.73
14B	424.5	7.86	7.38
18A	443.6	8.38	8.95
20A	529.6	12.37	11.13
mean		9.60	8.86
std. dev.		±3.99	±3.34
26A	486.9	15.22	8.95
30A	616.2	18.79	9.19
30B	616.2	14.66	7.32
32A	793.3	22.93	12.91
32B	793.3	18.79	10.97
32C	793.3	17.21	9.06
mean		17.93	9.73
std. dev.		±3.00	±1.94
37A	979.9	7.03	4.08
39B	982.9	3.76	2.13
40A	983.2	5.90	3.32
mean		5.56	3.17
std. dev.		±1.66	±0.98

Table 3 Uniaxial Compressive Test Results

Sample Number	Depth (m)	Q_u (MPa)	ε_{peak} (%)	E (GPa)	ν
1	403.4	111.98	0.14	80.75	0.39
20	529.6	158.54	0.18	82.16	0.16
29A	494.2	240.90	0.34	96.30	0.28
33	793.3	209.50	0.20	95.22	0.24
38	982.9	33.34	0.12	28.55	0.58

Table 4 Multi-stage Triaxial Test Results

	Sample	σ_3=30.0 MPa		σ_3=40.0 MPa		σ_3=50.0 MPa		σ_3=60.0 MPa		σ_3=70.0 MPa		σ_3=80.0 MPa		σ_3=90.0 MPa		σ_3=100.0 MPa	
No.	Depth (m)	σ_1 (MPa)	ε_{peak} (%)	σ_1 (MPa)	ε_{peak} (%)	σ_1 (MPa)	ε_{peak} (%)	σ_1 (MPa)	ε_{peak} (%)	σ_1 (MPa)	ε_{peak} (%)	σ_1 (MPa)	ε_{peak} (%)	σ_1 (MPa)	ε_{peak} (%)	σ_1 (MPa)	ε_{peak} (%)
1A	403.4	201.19	0.33	212.11	0.36	237.48	0.44	251.93	0.49	264.91	0.52	277.60	0.56	289.40	0.59	304.44	0.64
2A	405.2	247.03	0.40	264.69	0.44	273.82	0.47	281.18	0.50	290.90	0.52	304.15	0.56	310.63	0.58	322.70	0.67
3	405.2	184.08	0.29	(165.29)	(0.29)	224.88	0.43	223.71	0.47	271.56	0.64	297.40	0.75	309.44	0.80	328.52	1.01
3A	405.2	229.07	0.38	240.85	0.41	250.86	0.43	259.39	0.45	276.18	0.49	302.68	0.58	315.63	0.61	330.94	0.71
3B	405.2	218.47	0.35	234.07	0.40	250.86	0.44	266.46	0.48	282.65	0.52	297.67	0.55	312.69	0.59	327.11	0.68
4	405.2	231.49	0.35	254.14	0.40	270.03	0.44	285.91	0.48	298.56	0.51	312.38	0.55	325.92	0.59	338.27	0.67
5	408.5	223.26	0.38	252.08	0.46	281.50	0.55	310.62	0.65	331.21	0.71	353.86	0.79	369.16	0.83	383.27	0.95
5A	408.5	175.90	0.27	213.55	0.40	228.26	0.45	247.38	0.51	269.15	0.59	279.44	0.63	293.85	0.68	311.21	0.80
6	408.5	218.76	0.34	232.60	0.37	242.32	0.40	255.86	0.44	264.99	0.46	281.18	0.51	292.66	0.54	308.56	0.64
6A	408.5	199.14	0.33	214.14	0.37	226.79	0.40	238.55	0.44	251.79	0.48	261.79	0.51	271.79	0.53	277.68	0.61
	mean	212.84	0.34	235.36	0.40	248.68	0.45	262.10	0.49	280.19	0.54	296.82	0.60	309.12	0.63	323.27	0.74
	std. dev.	±22.29	±0.04	±19.36	±0.03	±20.56	±0.04	±25.16	±0.06	±22.47	±0.08	±25.23	±0.10	±26.31	±0.10	±27.33	±0.14
11	423.0	241.26	0.41	253.90	0.46	265.07	0.51	271.53	0.54	278.29	0.58	284.46	0.62	288.87	0.65	294.16	0.68
12	423.0	230.83	0.44	243.49	0.50	253.80	0.55	259.98	0.58	266.75	0.62	272.35	0.66	277.35	0.69	284.72	0.81
13	424.5	208.55	0.41	221.20	0.46	231.79	0.51	240.02	0.54	246.79	0.58	252.97	0.61	260.03	0.65	265.91	0.68
14	424.5	195.80	0.32	215.52	0.38	229.95	0.43	242.61	0.47	254.39	0.51	263.81	0.54	274.70	0.58	282.36	0.61
15	425.3	245.38	0.29	285.64	0.37	298.27	0.40	309.15	0.44	319.14	0.48	327.95	0.51	334.12	0.54	342.65	0.57
15A	425.3	289.19	0.35	300.63	0.37	311.48	0.39	322.34	0.42	332.31	0.44	341.99	0.46	351.37	0.49	360.17	0.51
16	425.3	240.97	0.31	251.25	0.33	258.60	0.34	267.71	0.36	276.53	0.38	287.11	0.40	297.68	0.43	307.68	0.45
17	443.6	228.41	0.36	255.42	0.43	268.04	0.46	278.90	0.49	288.88	0.52	300.63	0.55	312.37	0.58	320.89	0.61
18	443.6	292.94	0.44	315.95	0.49	333.65	0.54	354.00	0.61	371.41	0.66	387.34	0.72	399.43	0.76	411.23	0.80
19	529.6	349.11	0.58	378.50	0.66	409.94	0.76	439.33	0.86	463.42	0.93	486.93	1.01	509.56	1.07	530.13	1.14
	mean	252.24	0.39	272.15	0.45	286.06	0.49	298.56	0.53	309.79	0.57	320.55	0.61	330.55	0.64	339.99	0.69
	std. dev.	±45.73	±0.09	±49.32	±0.09	±54.83	±0.12	±61.18	±0.14	±66.18	±0.15	±71.17	±0.17	±75.50	±0.18	±79.59	±0.20

Table 4 Multi-stage Triaxial Test Results (cont'd)

	Sample	σ_3=30.0 MPa		σ_3=40.0 MPa		σ_3=50.0 MPa		σ_3=60.0 MPa		σ_3=70.0 MPa		σ_3=80.0 MPa		σ_3=90.0 MPa		σ_3=100.0 MPa	
No.	Depth (m)	σ_1 (MPa)	ε_{peak} (%)	σ_1 (MPa)	ε_{peak} (%)	σ_1 (MPa)	ε_{peak} (%)	σ_1 (MPa)	ε_{peak} (%)	σ_1 (MPa)	ε_{peak} (%)	σ_1 (MPa)	ε_{peak} (%)	σ_1 (MPa)	ε_{peak} (%)	σ_1 (MPa)	ε_{peak} (%)
21	273.8	72.15	0.18	101.72	0.22	116.86	0.26	130.93	0.29	144.29	0.32	155.87	0.35	165.85	0.38	194.35	0.56
22	273.8	107.85	0.22	120.34	0.28	123.34	0.30	132.84	0.32	145.34	0.36	155.88	0.39	168.73	0.43	176.59	0.45
24	275.0	136.40	0.26	147.30	0.29	166.61	0.34	171.25	0.35	190.02	0.42	197.00	0.44	207.90	0.49	217.55	0.52
25	275.0	126.95	0.22	(117.13)	(0.26)	133.74	0.29	151.23	0.34	164.80	0.37	174.45	0.39	185.34	0.42	195.16	0.44
	mean	110.84	0.22	123.12	0.26	135.14	0.30	146.56	0.33	161.11	0.37	170.80	0.39	181.96	0.43	195.91	0.49
	std. dev.	±28.39	±0.03	±22.92	±0.04	±22.10	±0.03	±18.83	±0.03	±21.46	±0.04	±19.54	±0.04	±19.31	±0.05	±16.78	±0.06
26	486.9	219.71	0.29	237.30	0.31	255.06	0.34	271.05	0.37	286.14	0.39	299.64	0.41	315.80	0.44	332.50	0.47
27	494.2	302.17	0.37	326.36	0.40	350.37	0.44	368.77	0.47	385.78	0.50	394.36	0.52	417.32	0.56	434.15	0.59
28	494.2	367.94	0.40	391.33	0.43	419.82	0.46	439.52	0.49	459.22	0.51	490.17	0.55	514.09	0.59	534.50	0.63
29	494.2	411.20	0.44	426.33	0.47	462.03	0.51	504.24	0.56	532.91	0.59	564.92	0.63	595.00	0.67	635.80	0.78
30	616.2	236.61	0.30	261.10	0.33	278.72	0.36	318.36	0.42	331.58	0.44	340.21	0.46	353.42	0.48	380.03	0.58
31	793.3	451.77	0.49	501.67	0.55	540.58	0.60	578.59	0.66	598.40	0.69	615.15	0.72	628.48	0.74	652.98	0.79
	mean	331.57	0.38	357.35	0.42	384.56	0.45	413.42	0.50	432.34	0.52	450.74	0.55	470.69	0.58	494.99	0.64
	std. dev.	±94.35	±0.08	±101.37	±0.09	±110.32	±0.10	±116.20	±0.10	±120.09	±0.11	±126.37	±0.11	±128.71	±0.11	±133.92	±0.12
34	979.6	91.32	0.33	99.91	0.36	109.37	0.41	117.61	0.45	124.79	0.49	131.81	0.53	136.89	0.57	142.50	0.61
34A	979.9	82.16	0.30	90.21	0.35	103.00	0.42	108.96	0.45	114.39	0.48	119.29	0.50	125.25	0.54	131.03	0.64
35	979.6	82.31	0.36	91.98	0.41	98.67	0.45	105.53	0.49	110.10	0.51	115.55	0.55	119.42	0.57	126.81	0.65
36	979.9	81.37	0.29	90.67	0.33	100.84	0.38	108.56	0.41	114.34	0.43	119.43	0.46	—	—	—	—
36A	979.9	83.25	0.35	90.27	0.38	95.35	0.41	101.31	0.43	107.44	0.47	112.70	0.49	118.66	0.53	124.27	0.56
37	979.9	89.86	0.32	101.07	0.37	112.11	0.42	122.45	0.46	128.93	0.49	138.56	0.54	143.82	0.57	149.07	0.59
39	982.9	85.38	0.38	95.74	0.44	104.70	0.49	111.03	0.53	115.24	0.56	119.11	0.58	124.20	0.62	128.24	0.65
39A	982.9	89.62	0.40	97.33	0.44	105.22	0.49	109.61	0.52	112.77	0.54	115.57	0.56	118.38	0.58	121.71	0.60
40	983.2	75.24	0.30	(53.89)	(0.32)	(61.59)	(0.34)	(68.06)	(0.37)	(74.01)	(0.39)	(79.96)	(0.42)	(85.04)	(0.44)	(90.11)	(0.46)
41	983.2	87.01	0.34	93.34	0.37	104.24	0.44	109.86	0.47	114.61	0.51	118.65	0.54	121.99	0.57	124.98	0.59
	mean	84.75	0.34	94.50	0.38	103.72	0.43	110.55	0.47	115.85	0.50	121.19	0.53	126.08	0.57	131.08	0.61
	std. dev.	±4.89	±0.04	±4.19	±0.04	±5.13	±0.04	±6.23	±0.04	±6.81	±0.04	±8.42	±0.04	±9.34	±0.03	±9.65	±0.03

Table 5 Geological Classification

Borehole		Rock Type	Depth Interval (m)
4227		Rhyolite	403.4 - 411.3
4227		Massive Sulphide Zn	423.0 - 423.2
4227		Zn + Pb	424.5 - 424.7
4227		Zn + Py	425.3 - 425.6
4227		Cp + Po	443.6 - 443.9
4227		Cp stringer	529.6 - 529.9
4050		Andesite	273.8 - 275.3
4050		Andesite	486.9 - 494.8
4050		Andesite	616.2 - 793.8
4050		Talc/Carbonate	979.6 - 983.5

Table 6 Hoek and Brown m and s material constants

Rock Type	Depth Interval (m)	σ_3 Range (MPa)	σ_t (MPa)	Q_u (MPa)	Q_c (MPa)	m	s	r^2	m_r	s_r	r_r^2
Rhyolite	403.4 - 411.3	30.0-100.0	-12.48	111.98	122.77	3.29	1.00	0.90	2.98	0.00	0.85
Sulphide Zinc	423.0 - 529.9	30.0-100.0	-8.86	158.54	157.47	2.80	1.00	0.71	2.88	0.30	0.75
Andesite (weak)	273.8 - 275.3	30.0-100.0	-9.73	-	59.87	1.04	1.00	0.87	-	-	-
Andesite (strong)	486.9 - 793.8	30.0-100.0	-9.73	225.20	208.96	5.83	1.00	0.93	1.16	0.00	0.46
Talc-Carb	979.6 - 983.5	30.0-40.0	-3.17	33.34	27.64	2.27	1.00	0.92	0.06	0.30	

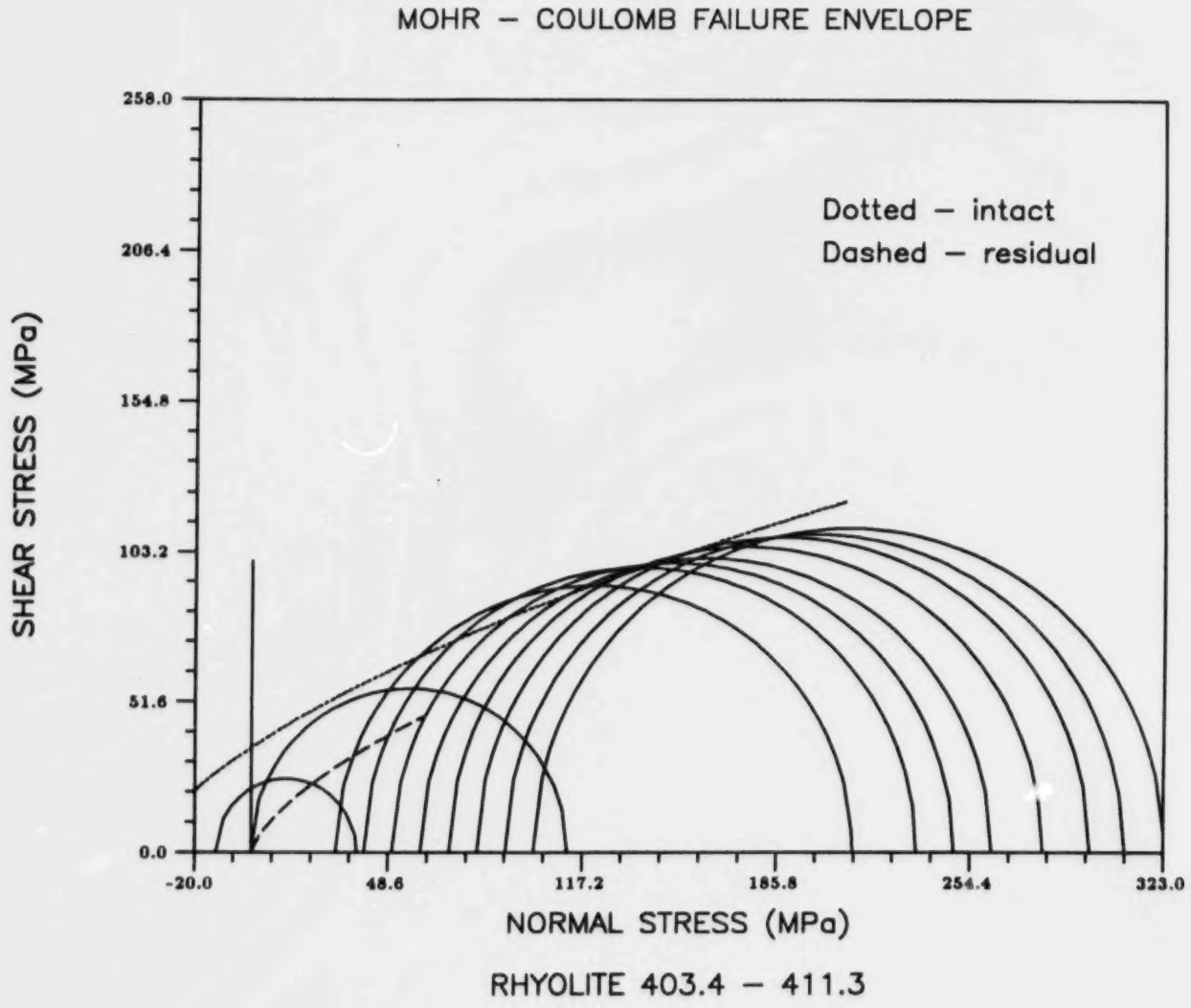


FIG.1 SPECIMENS 1 - 8B

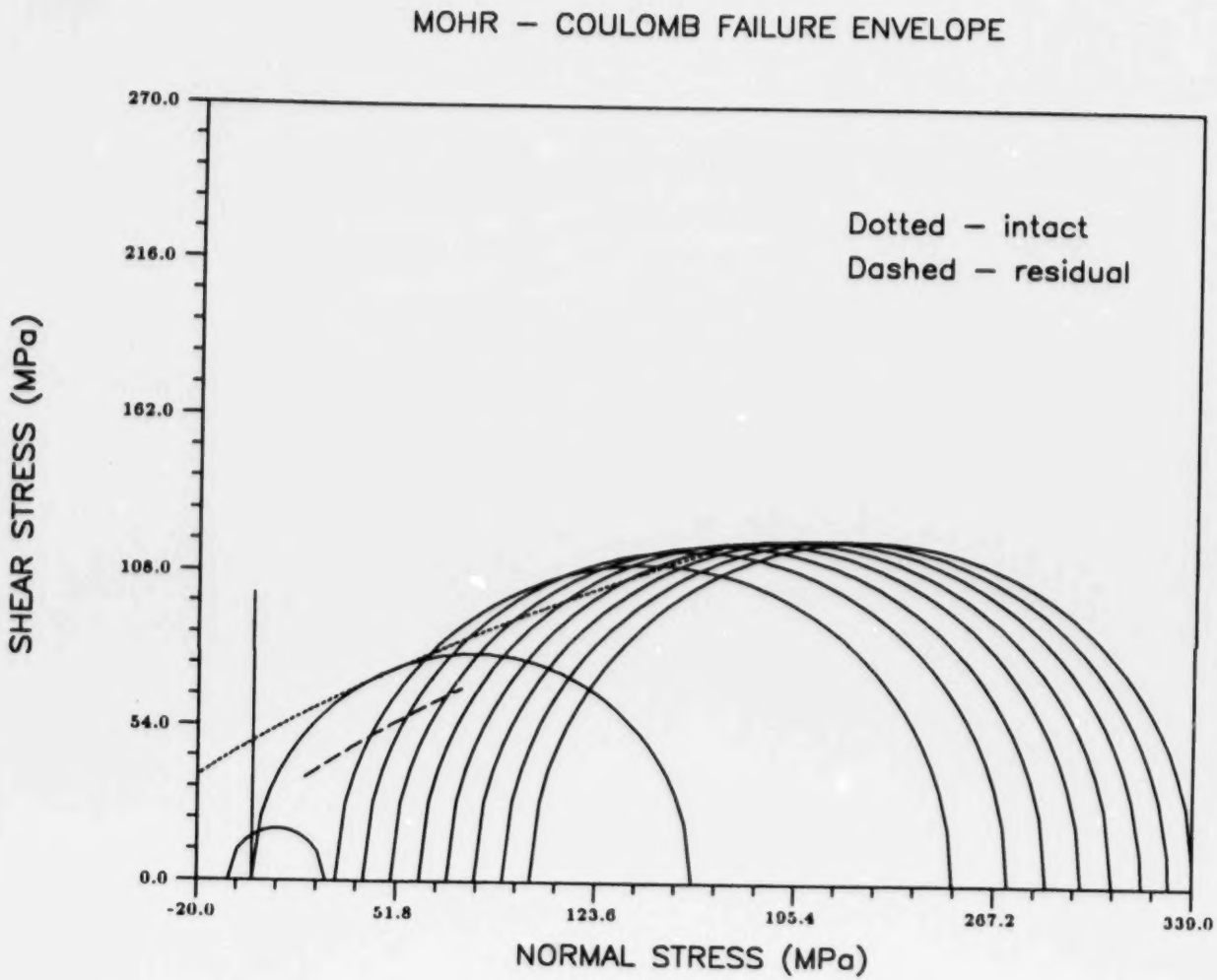


FIG.2 SPECIMENS 11 – 20A

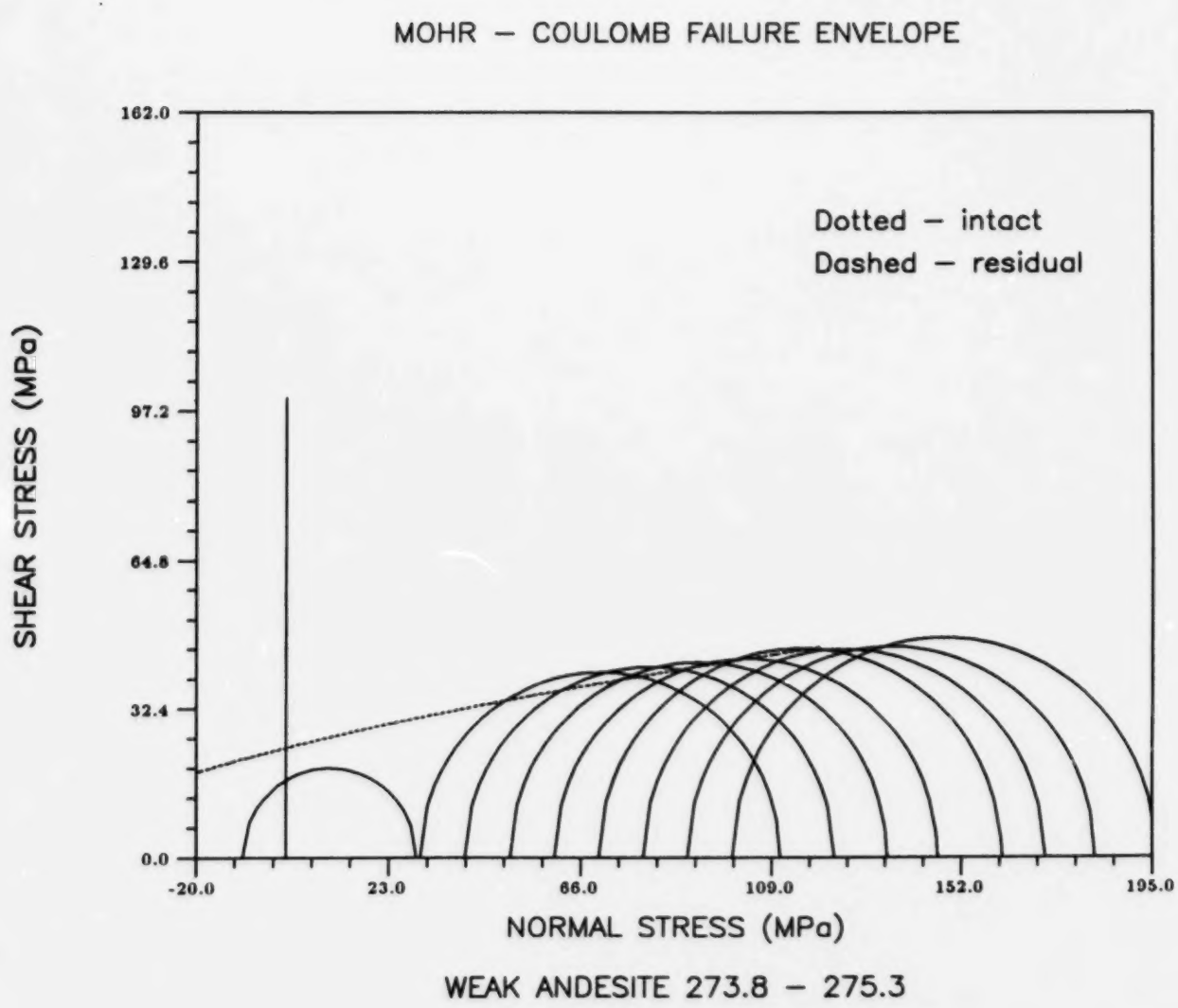


FIG.3 SPECIMENS 21 - 25

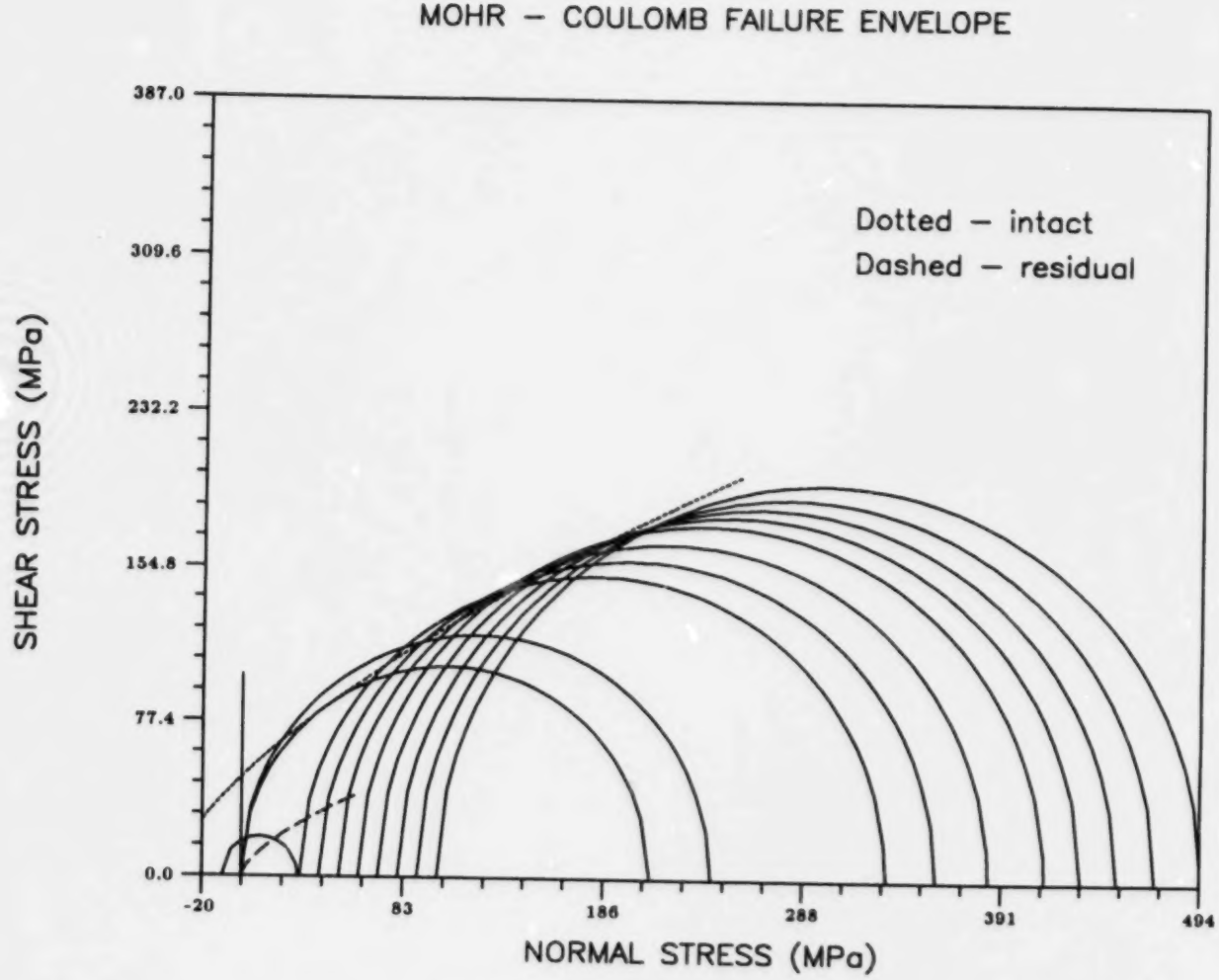
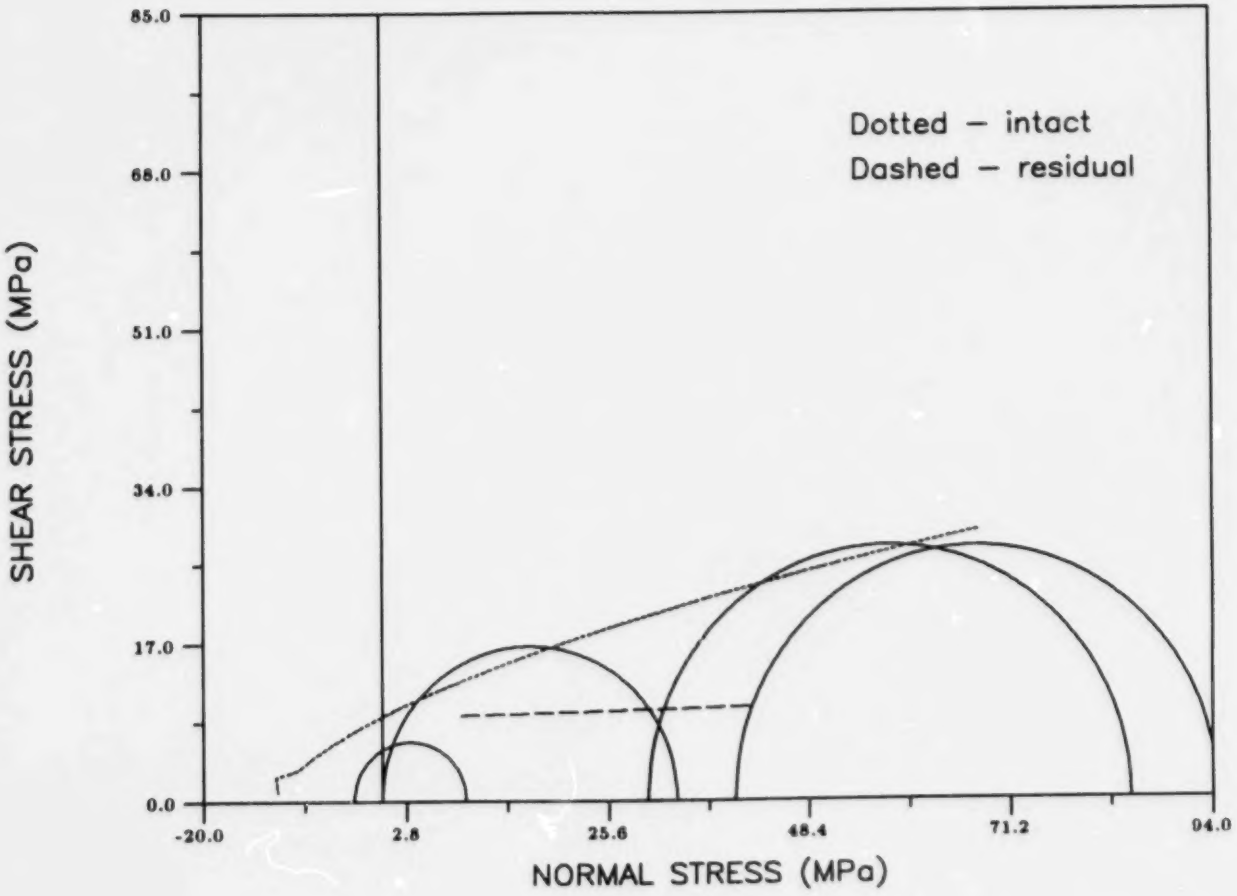


FIG. 4 SPECIMENS 26 - 33

MOHR – COULOMB FAILURE ENVELOPE



TALC/CARBONATE 979.6 – 983.5

FIG.5 SPECIMENS 34 - 41

APPENDIX A

STRESS-STRAIN CURVES OF UNIAXIAL TESTS USING STRAIN GAUGES

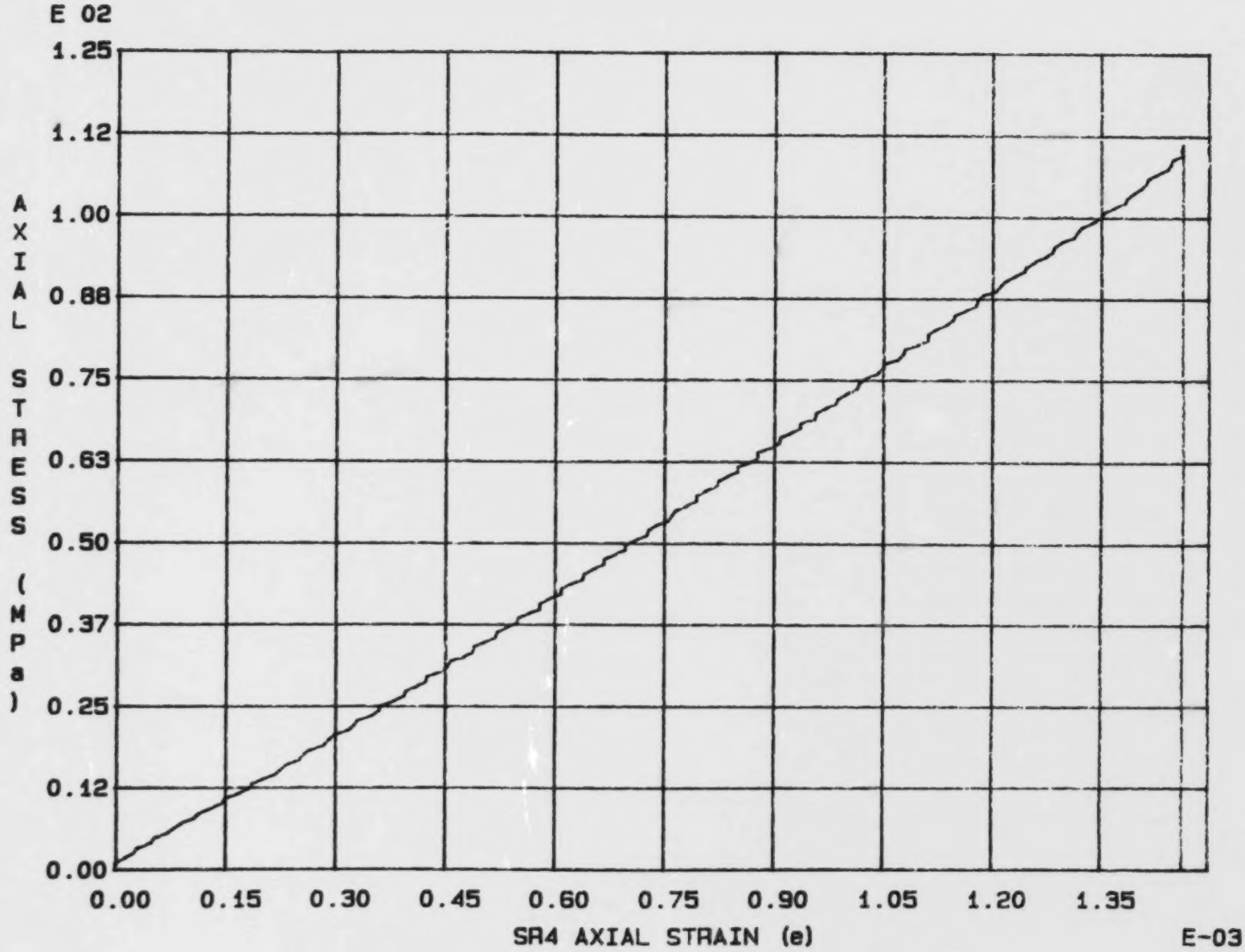


FIG.6 SPECIMEN 1

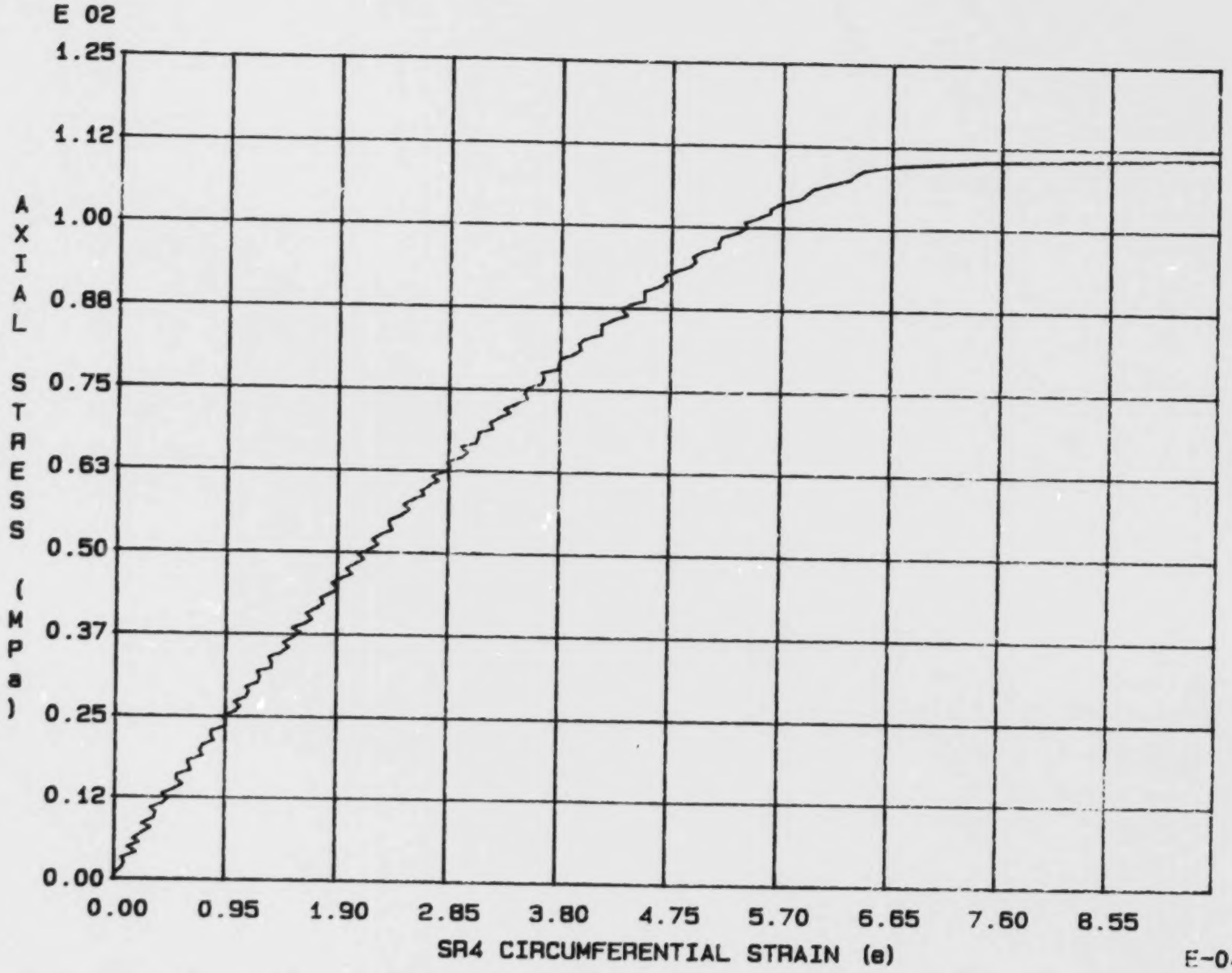


FIG.7 SPECIMEN 1

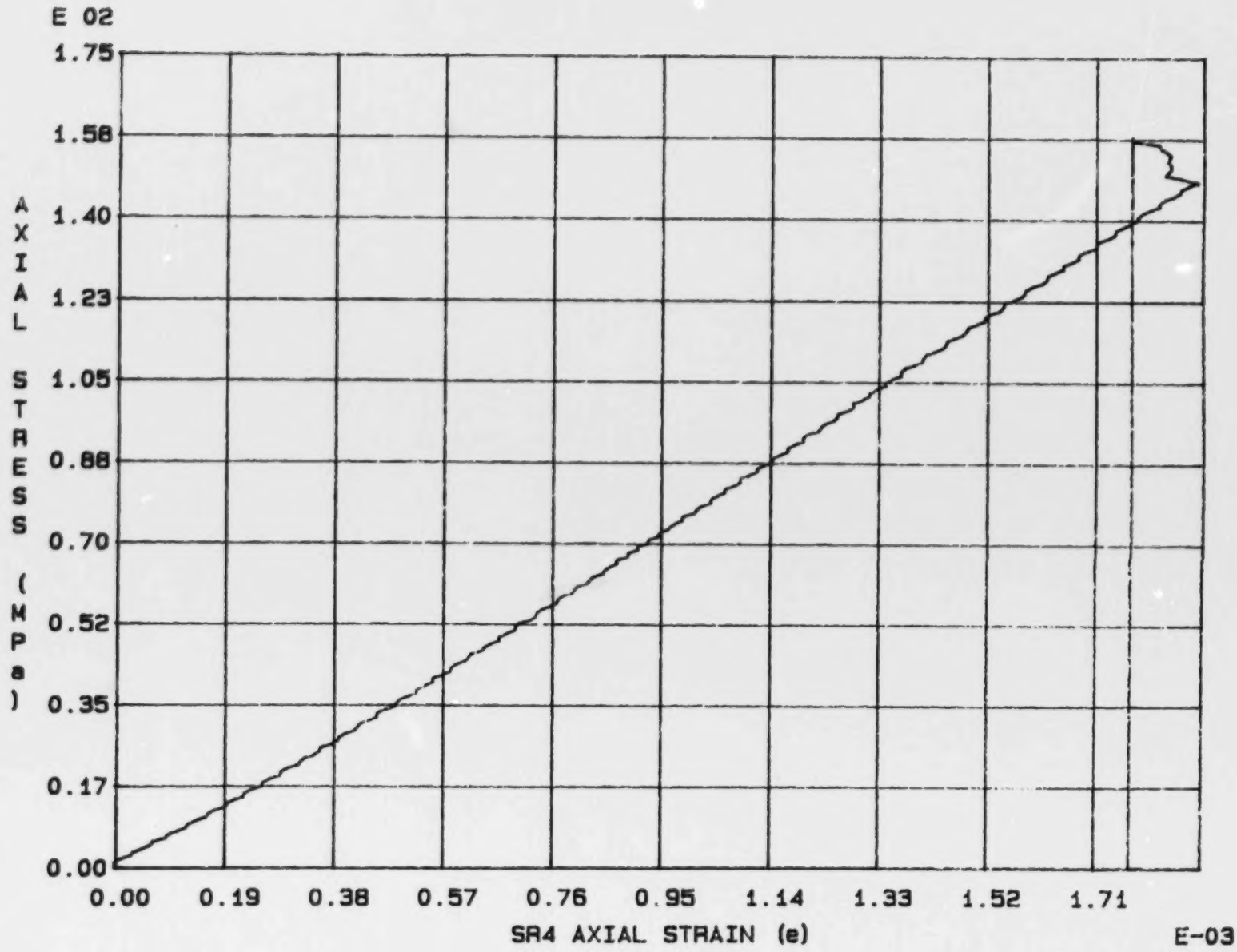


FIG.8 SPECIMEN 20

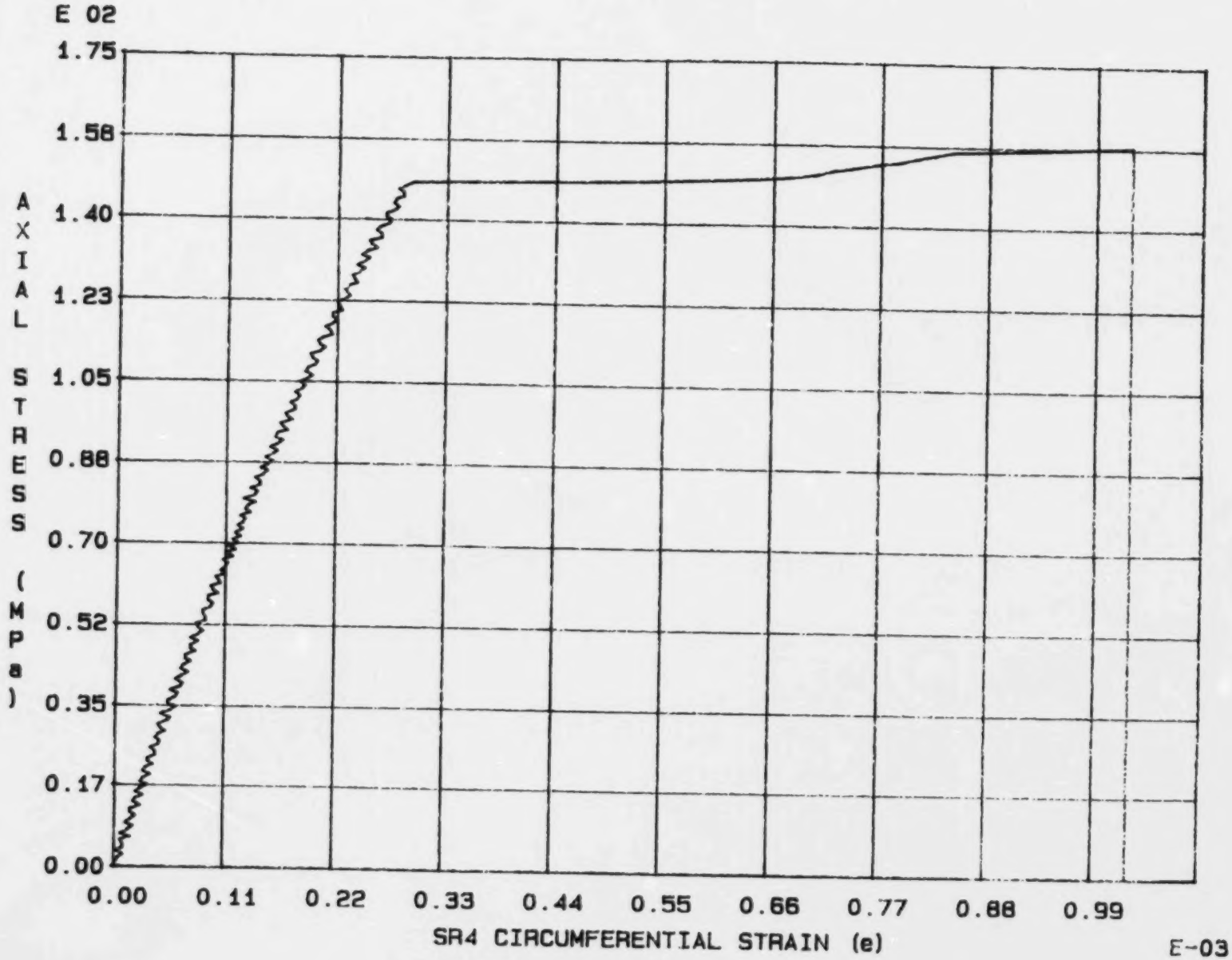


FIG.9 SPECIMEN 20

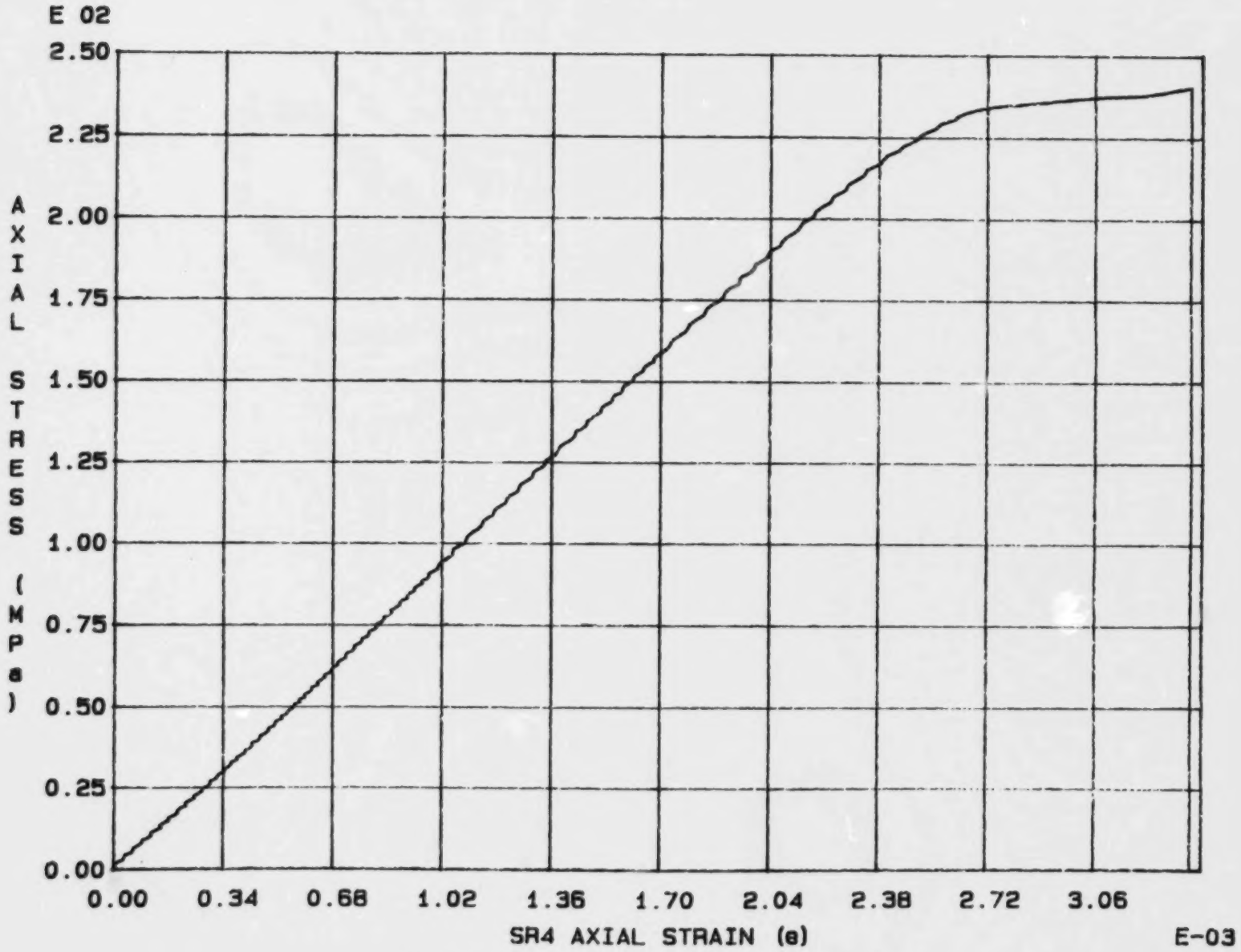


FIG.10 SPECIMEN 29A

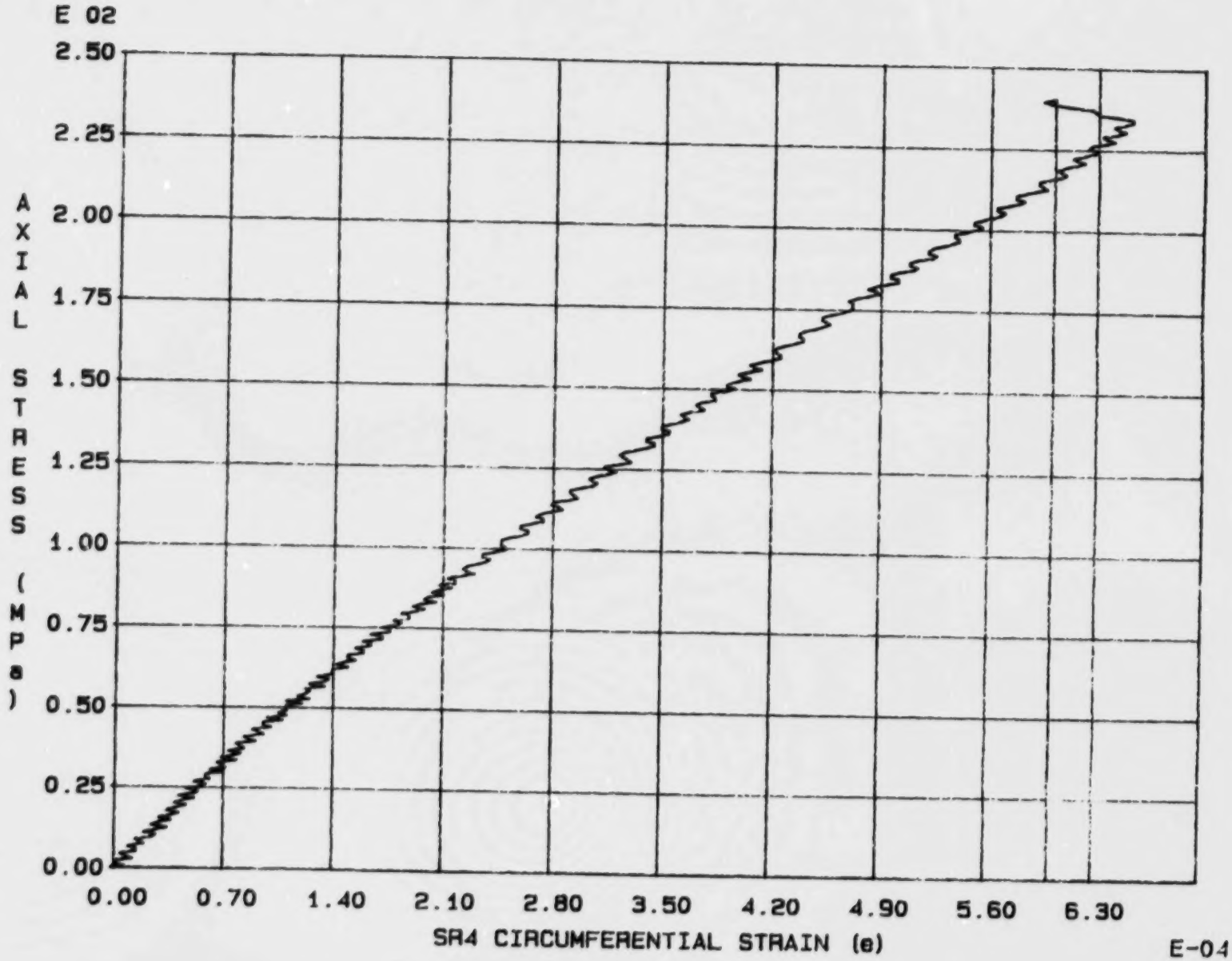


FIG.11 SPECIMEN 29A

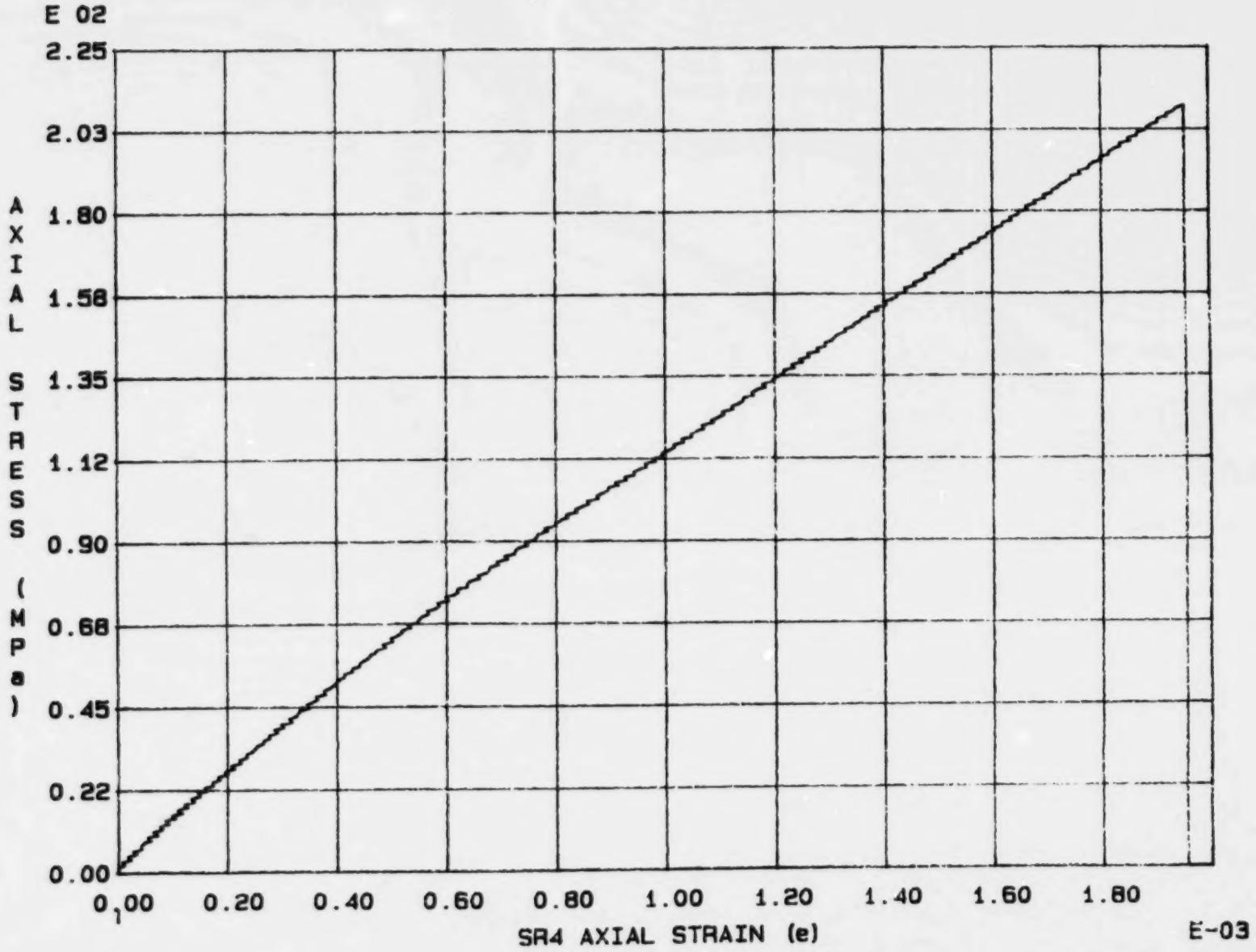


FIG.12 SPECIMEN 33

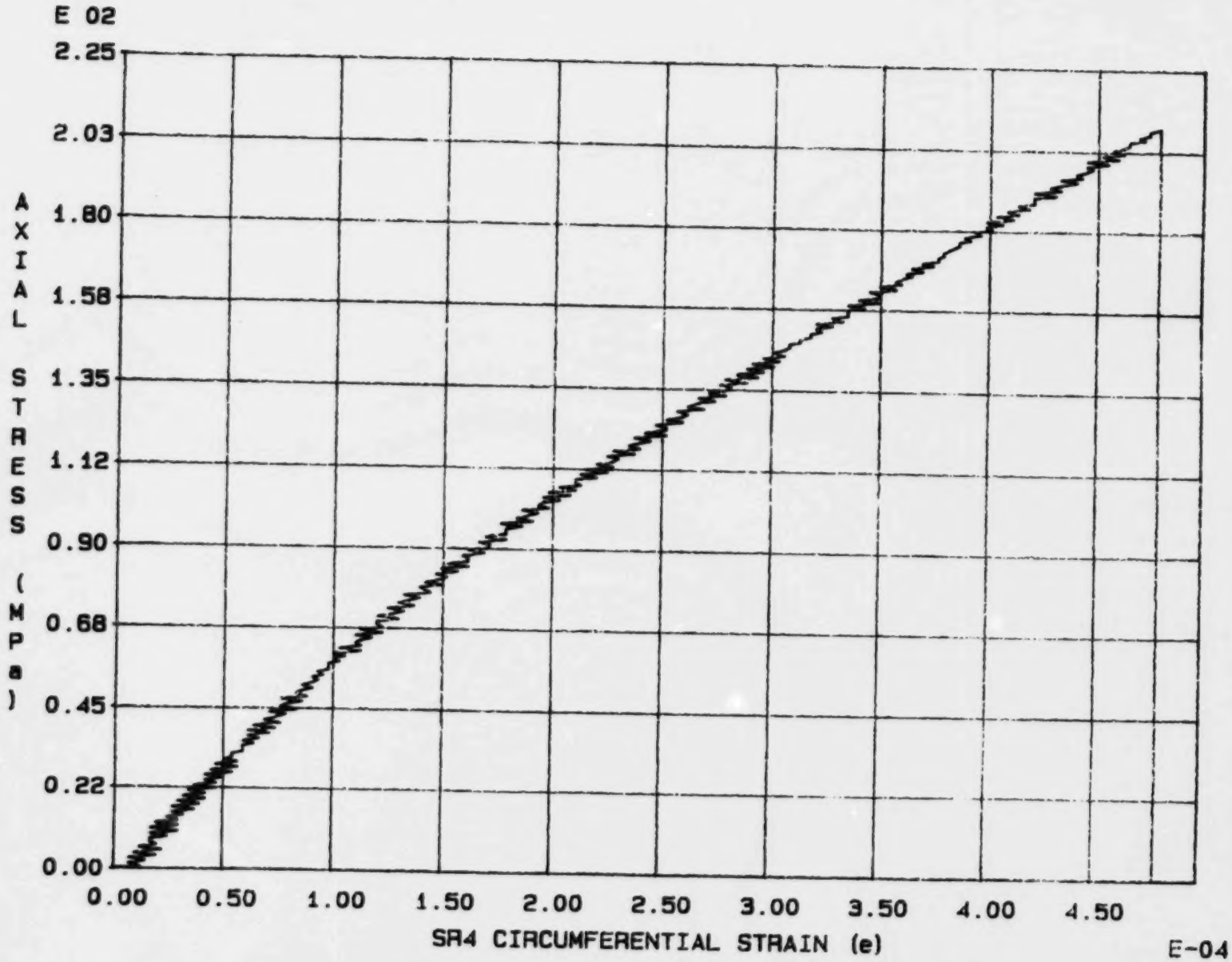


FIG.13 SPECIMEN 33

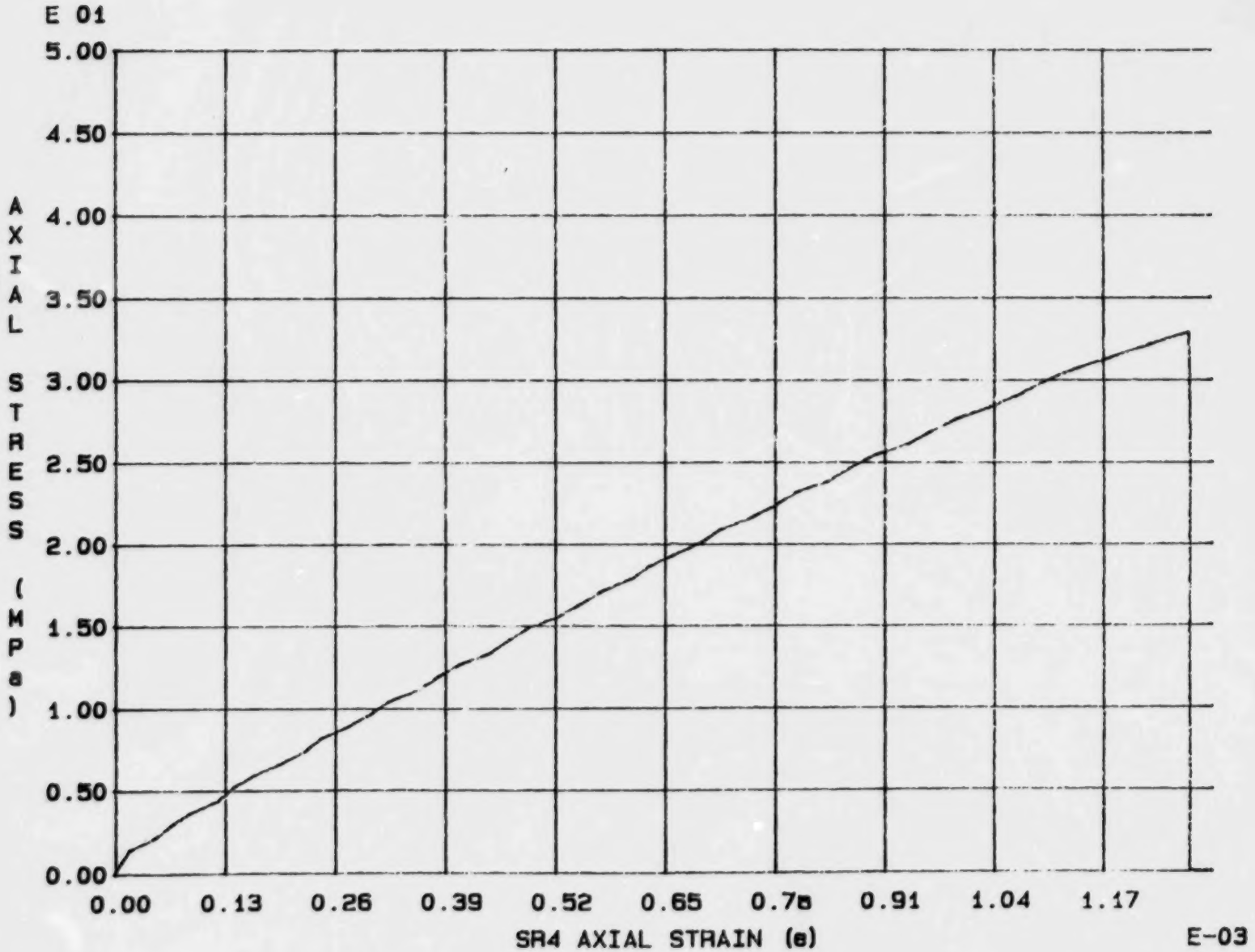


FIG.14 SPECIMEN 38

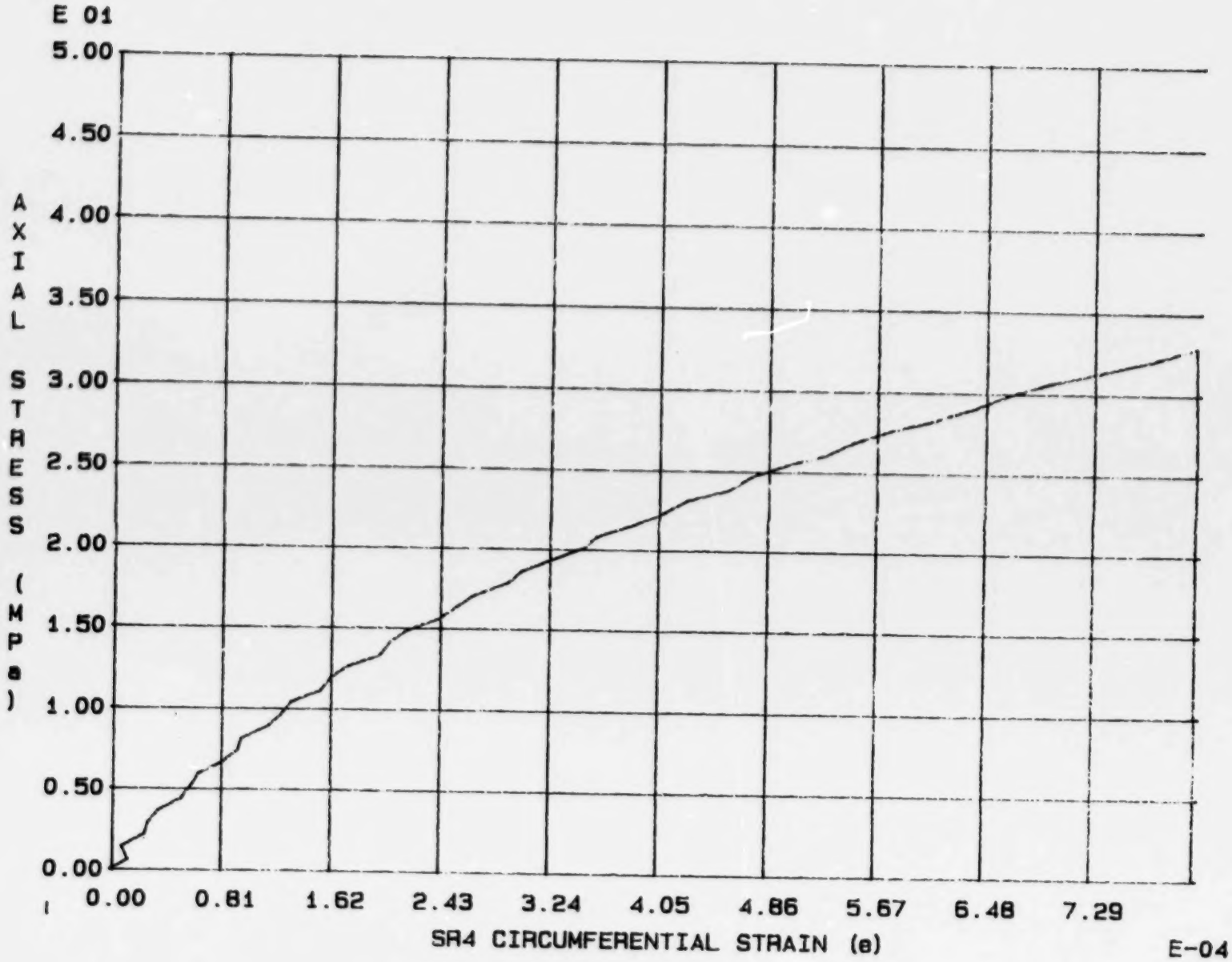


FIG.15 SPECIMEN 38

APPENDIX B

STRESS-STRAIN CURVES OF TRIAXIAL TESTS USING LVDTS

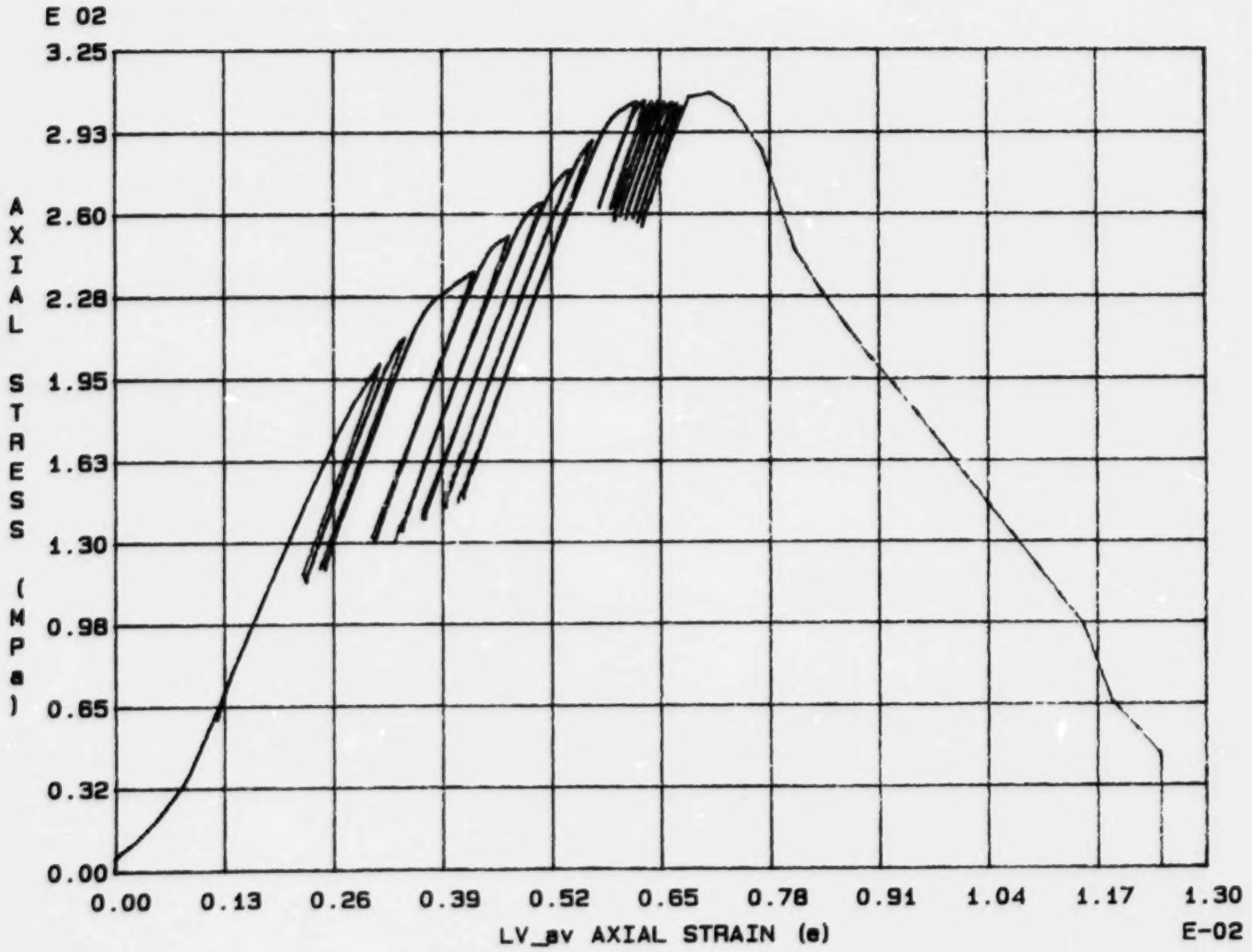


FIG.16 SPECIMEN 1A

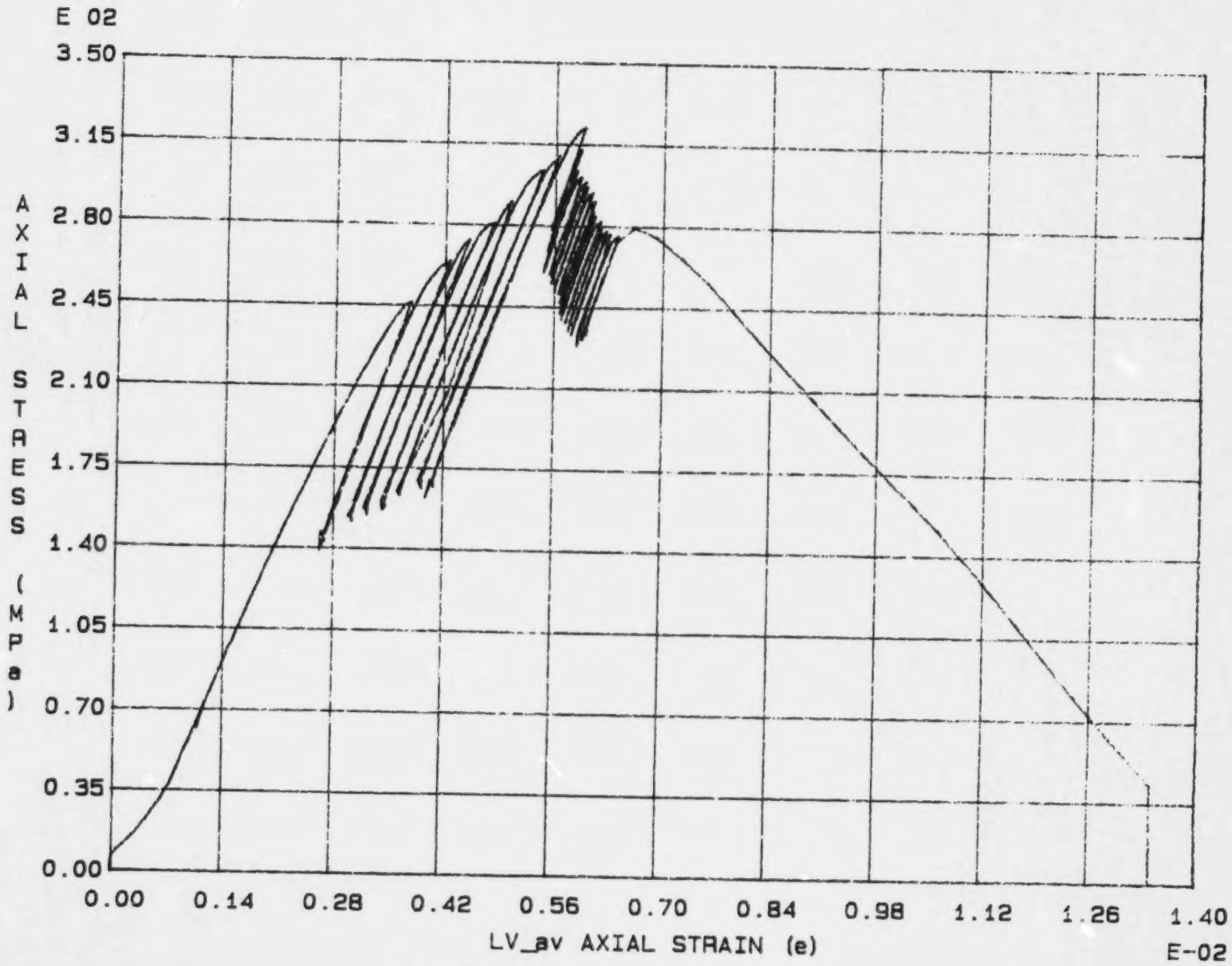


FIG.17 SPECIMEN 2A

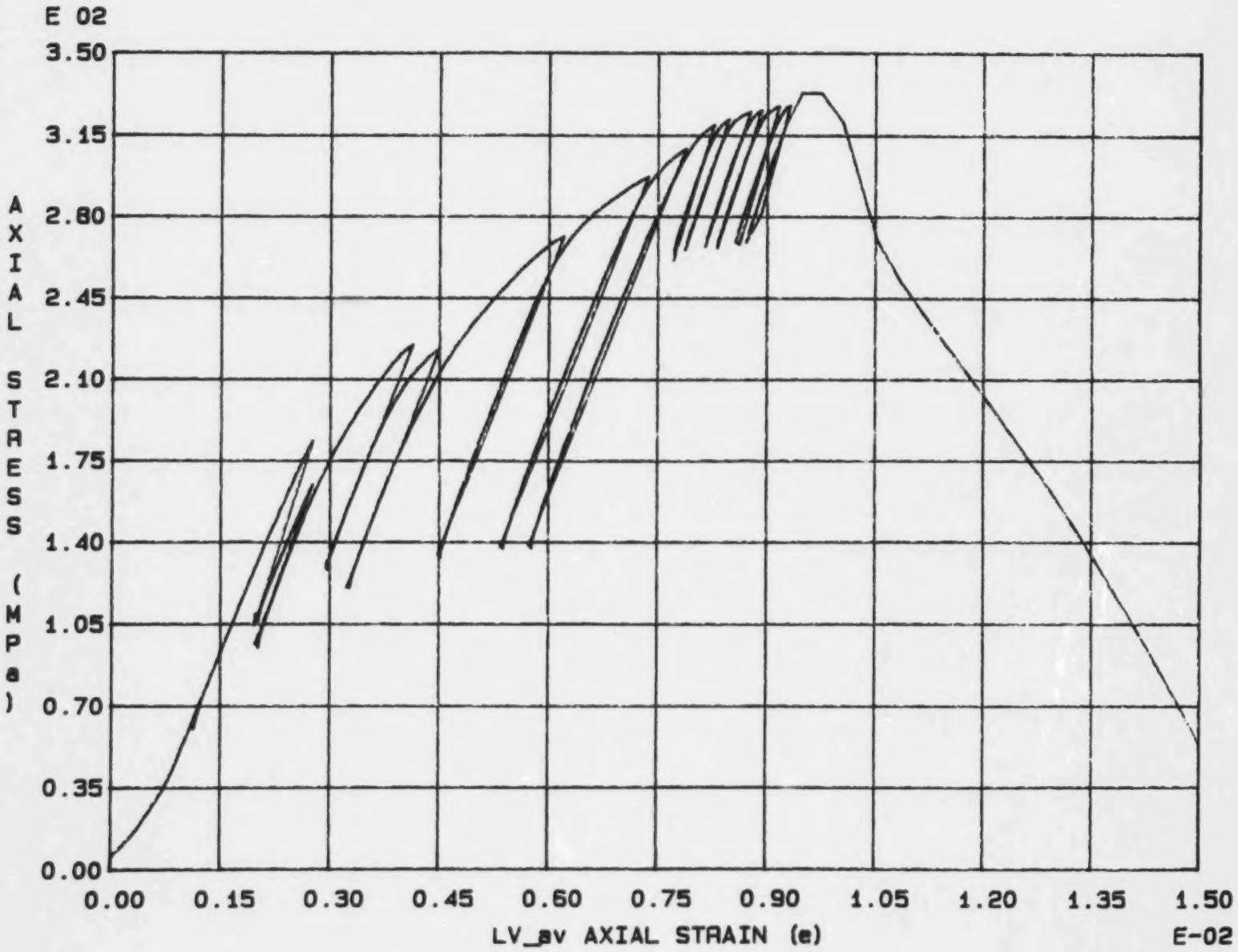


FIG.18 SPECIMEN 3

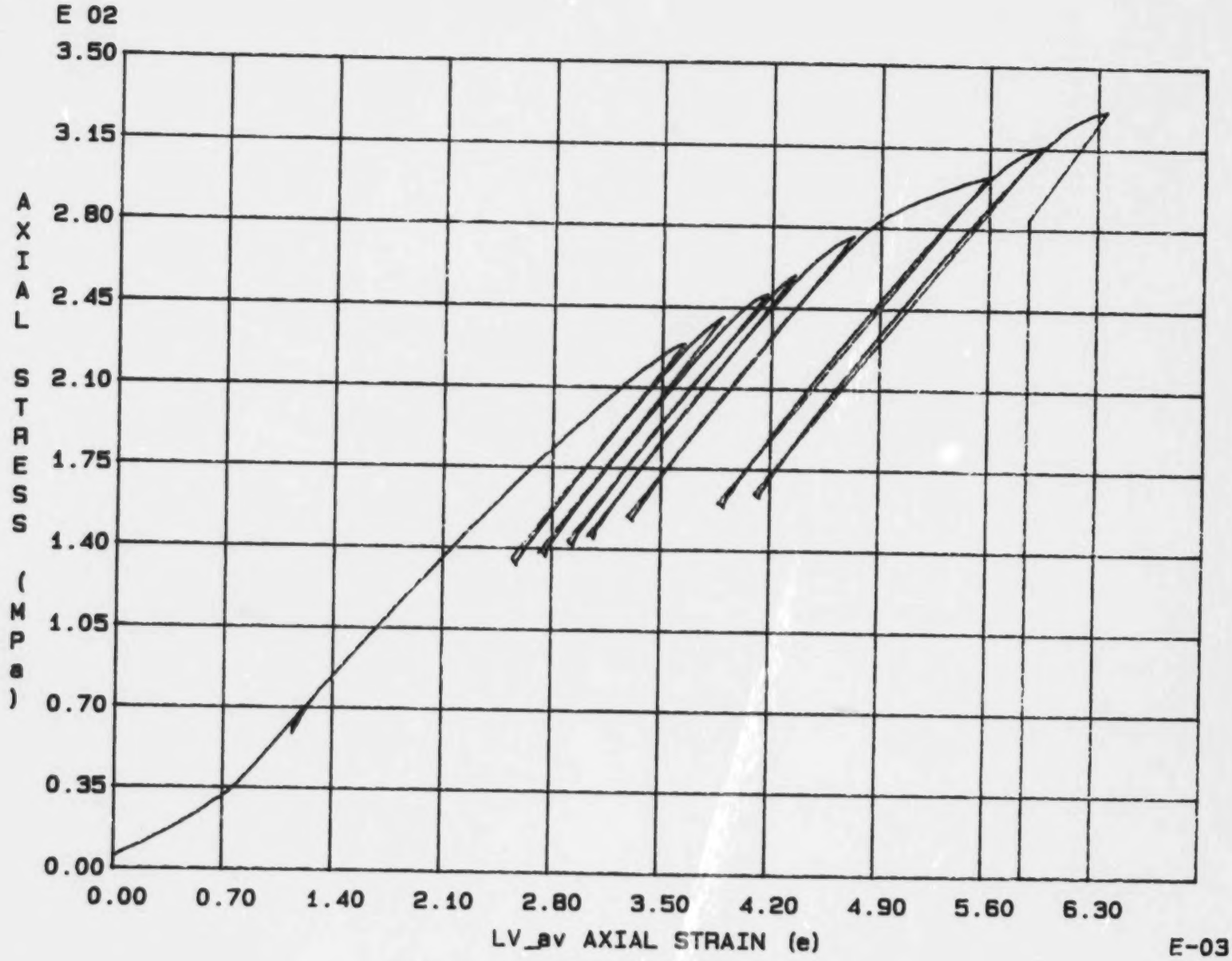


FIG.19 SPECIMEN 3A

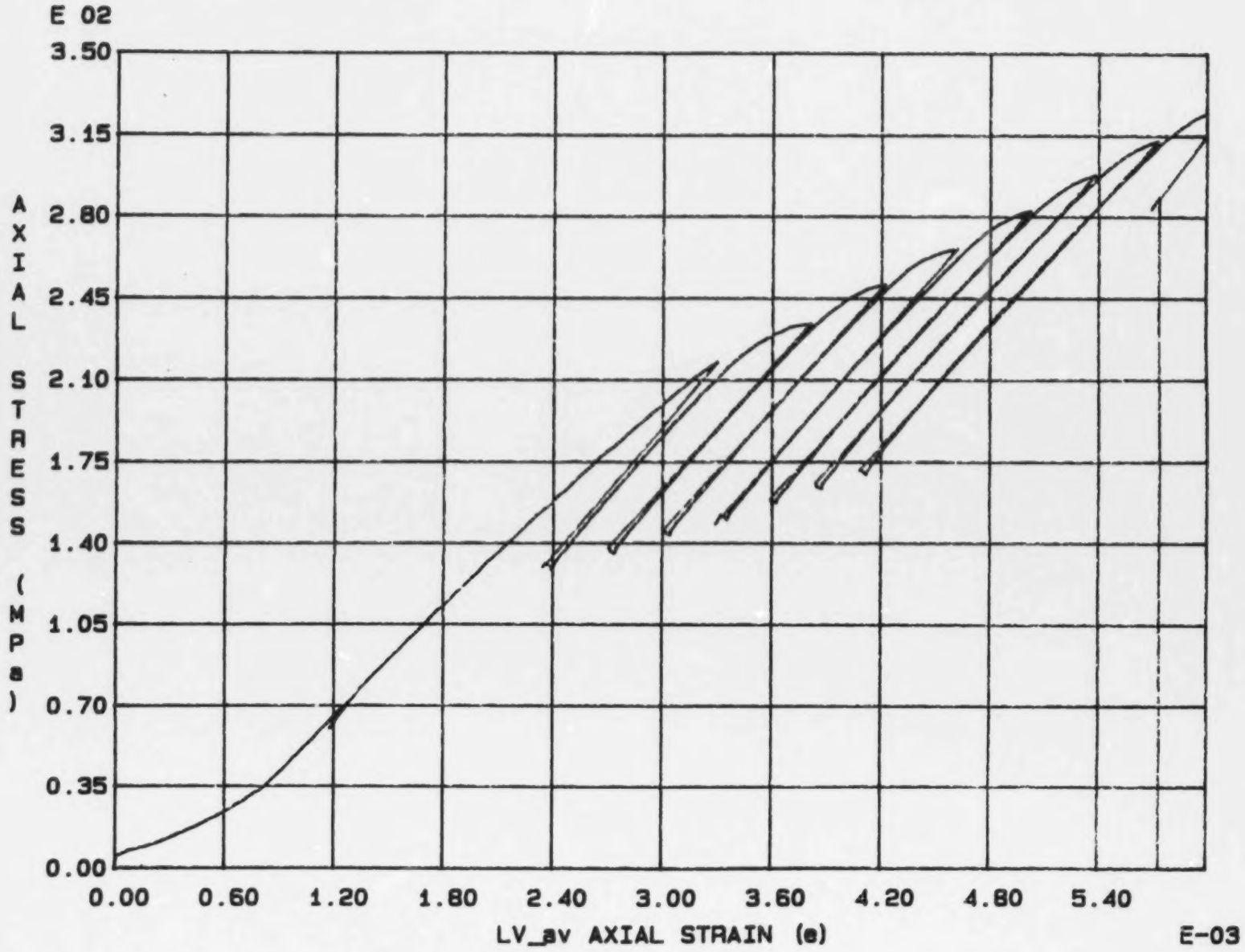


FIG.20 SPECIMEN 3B

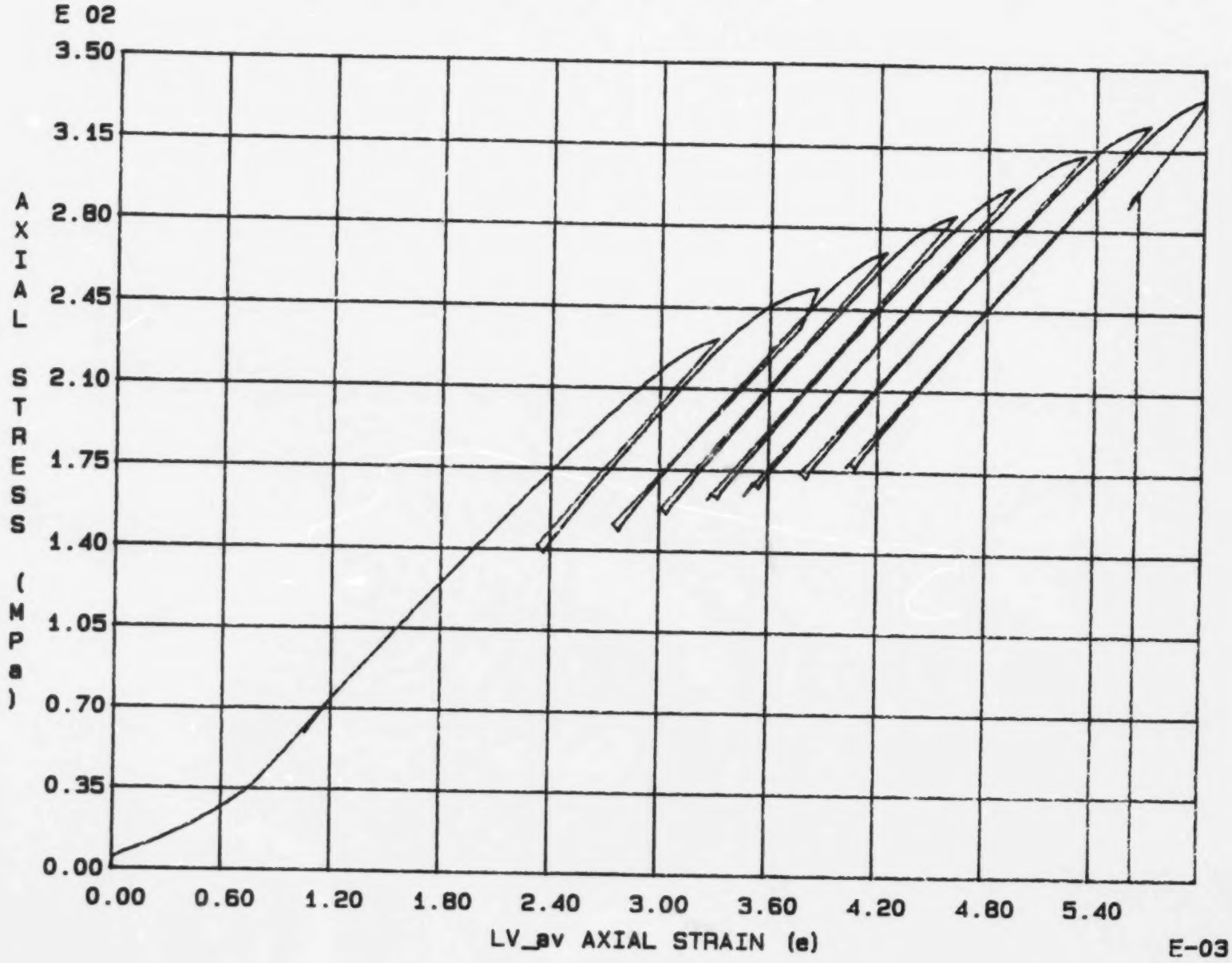


FIG.21 SPECIMEN 4

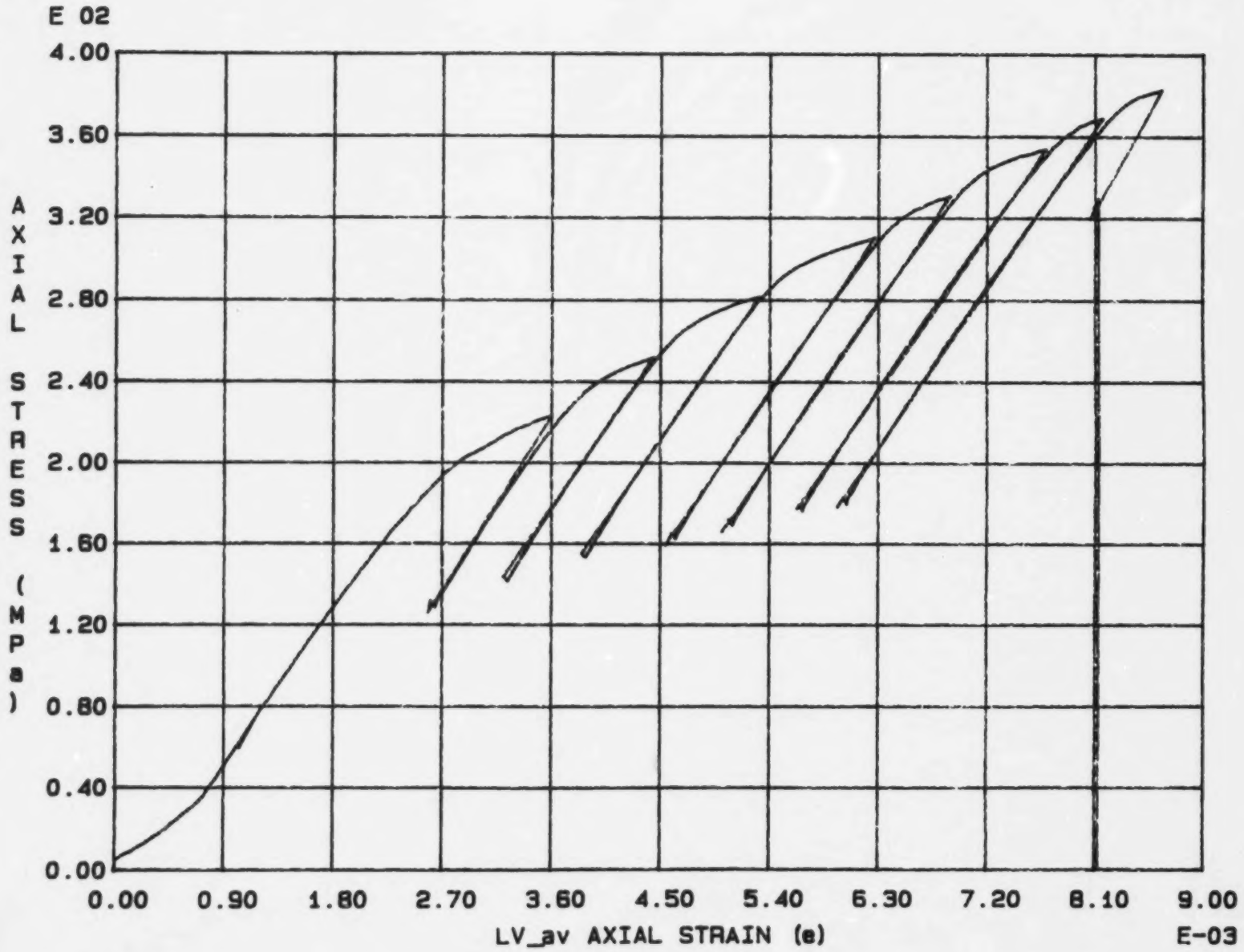


FIG.22 SPECIMEN 5

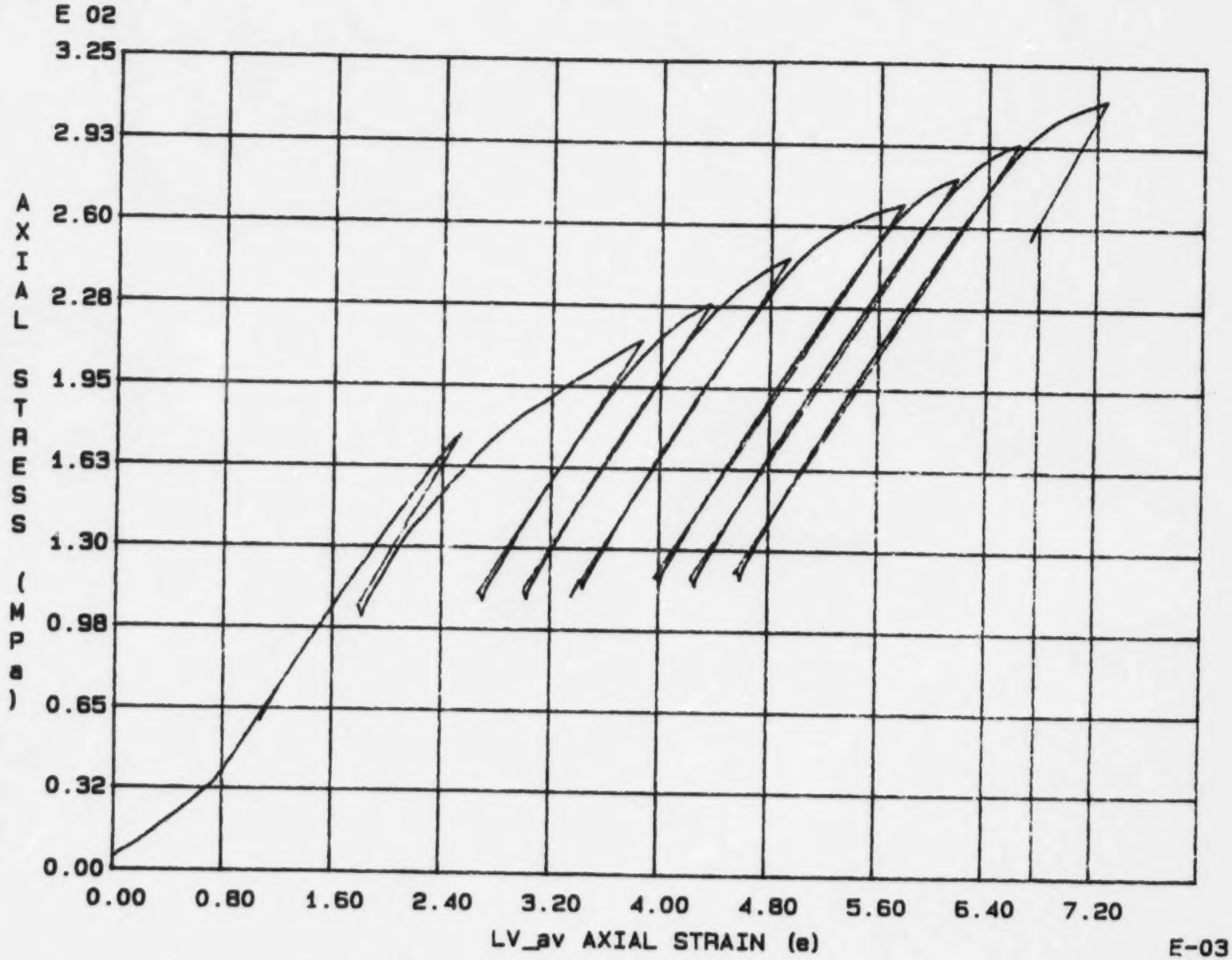


FIG.23 SPECIMEN 5A

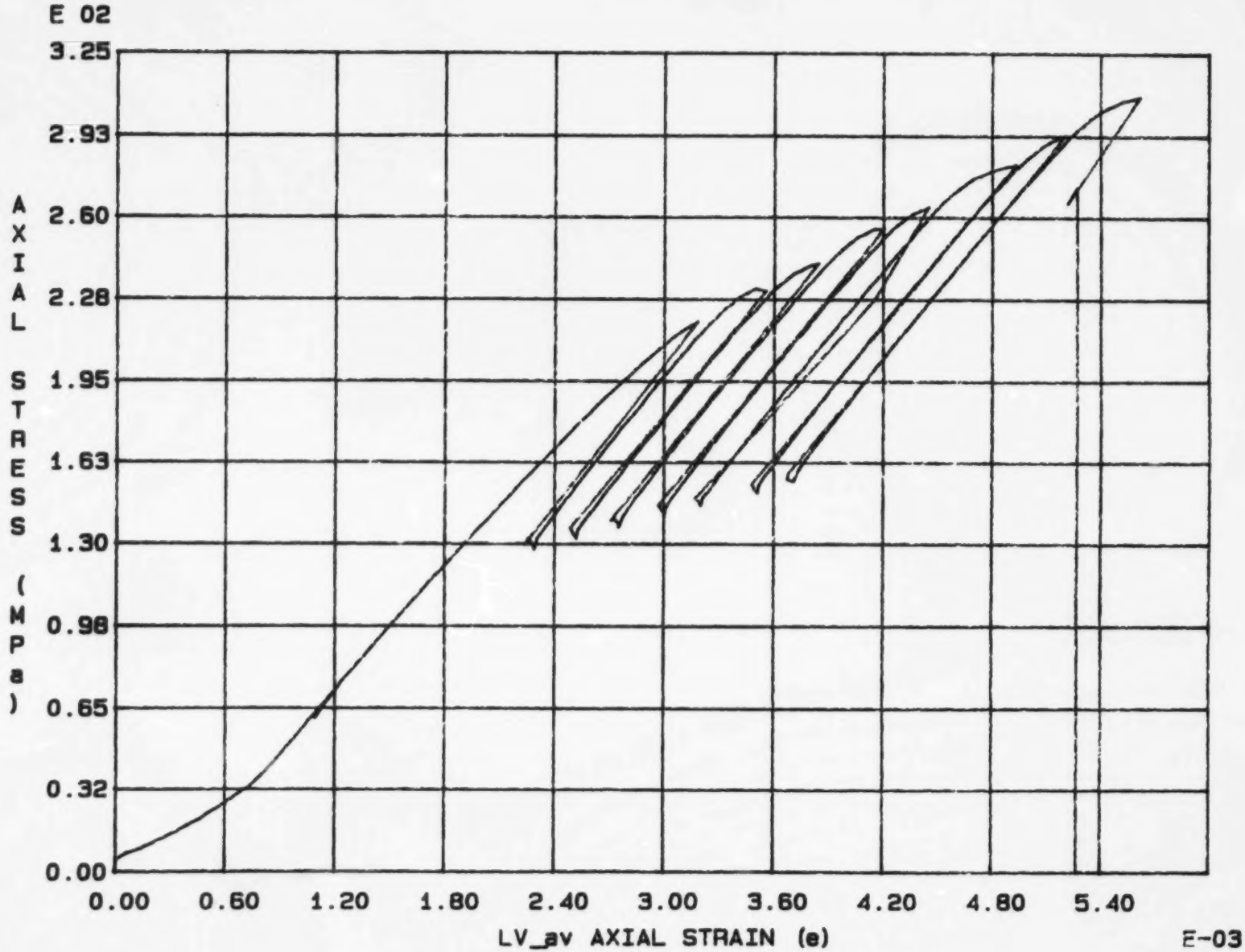


FIG.24 SPECIMEN 6

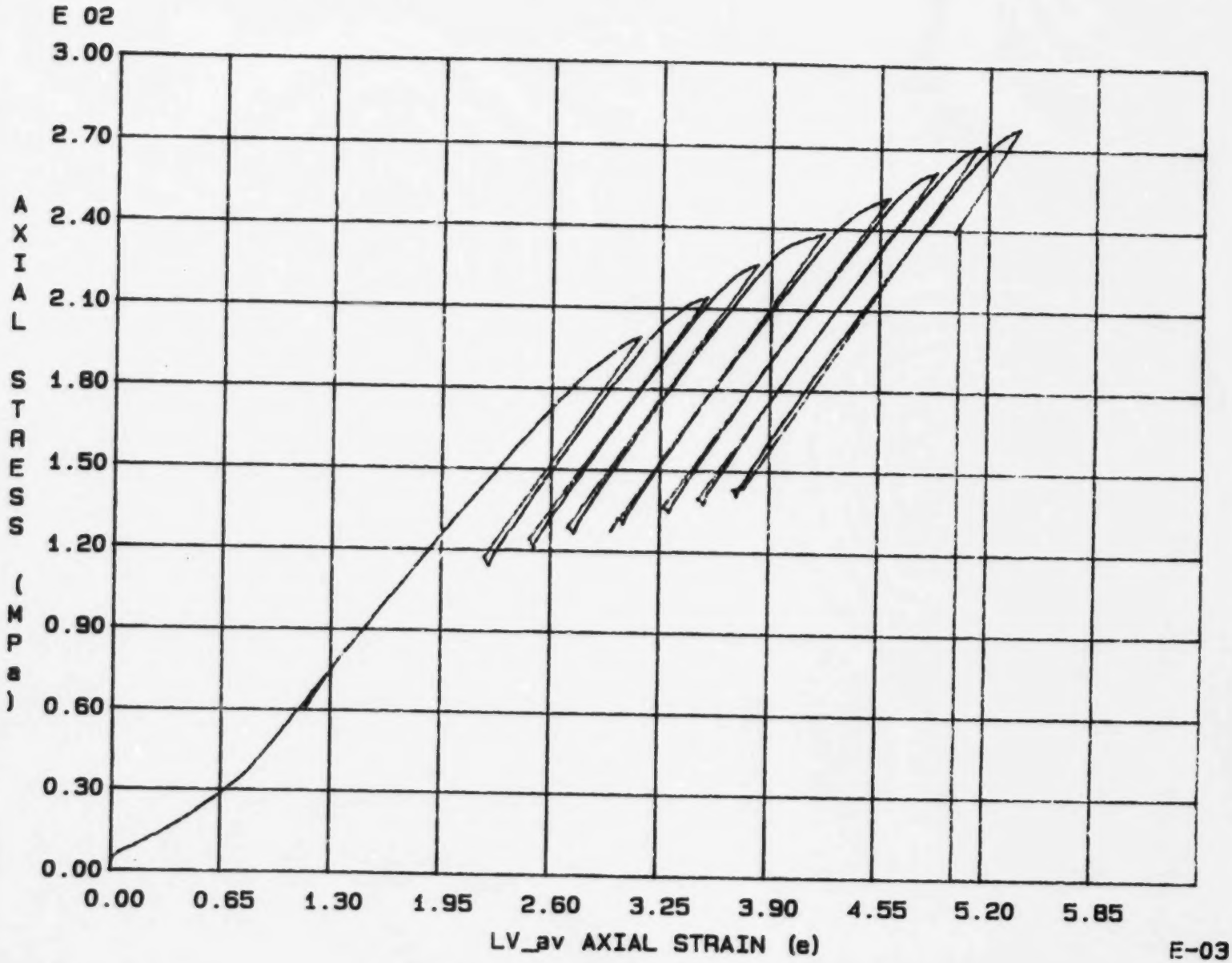


FIG.25 SPECIMEN 6A

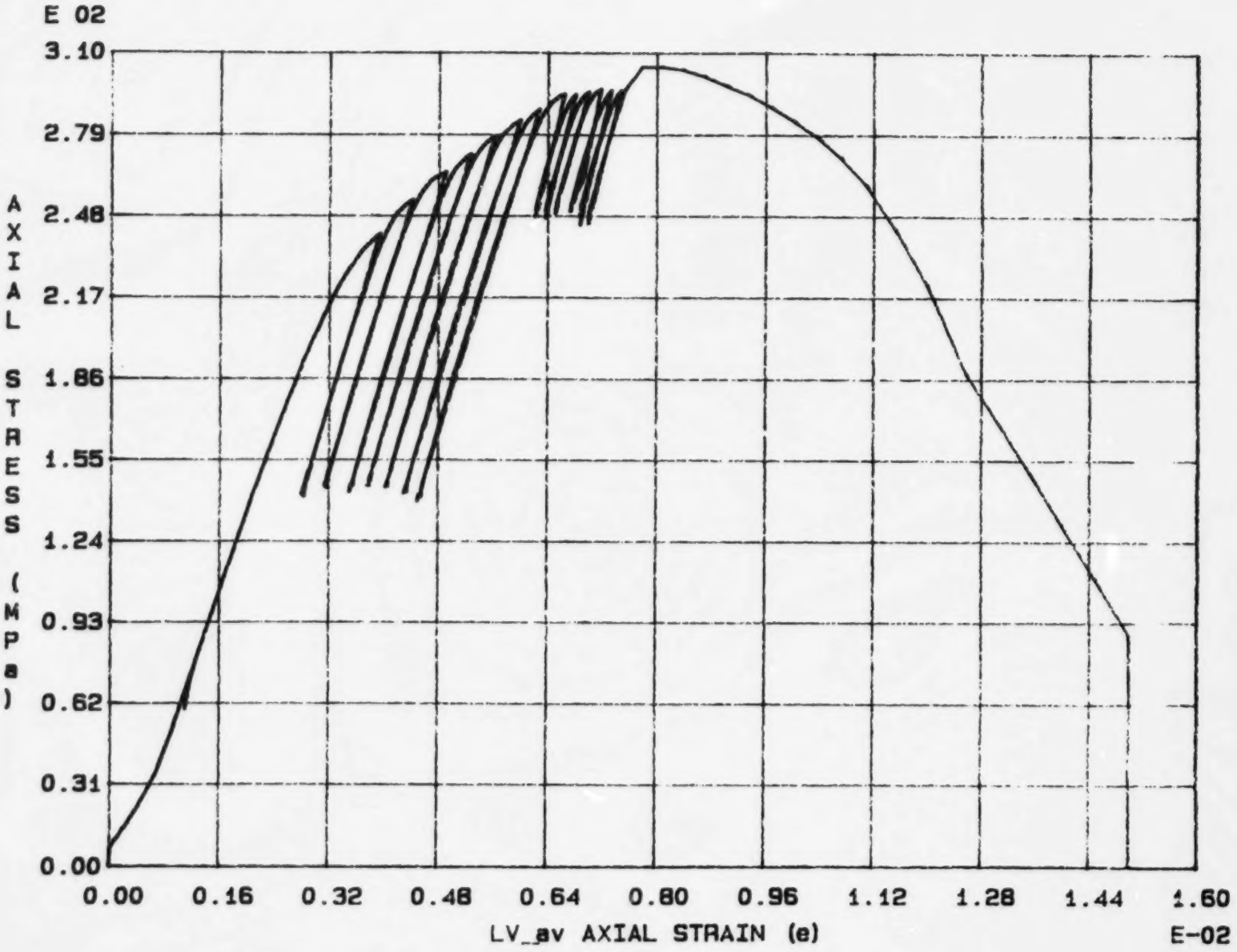


FIG.26 SPECIMEN 11

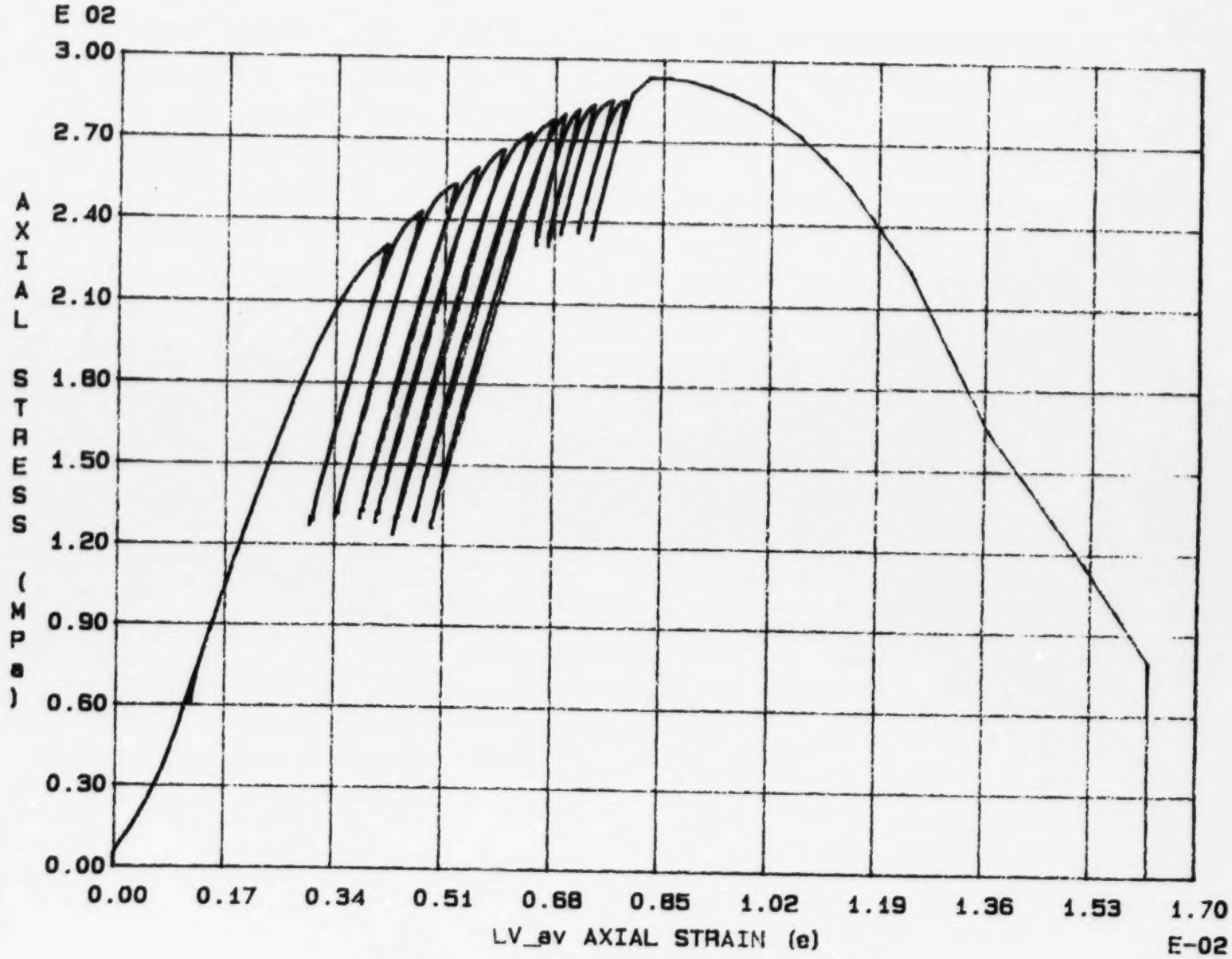


FIG.27 SPECIMEN 12

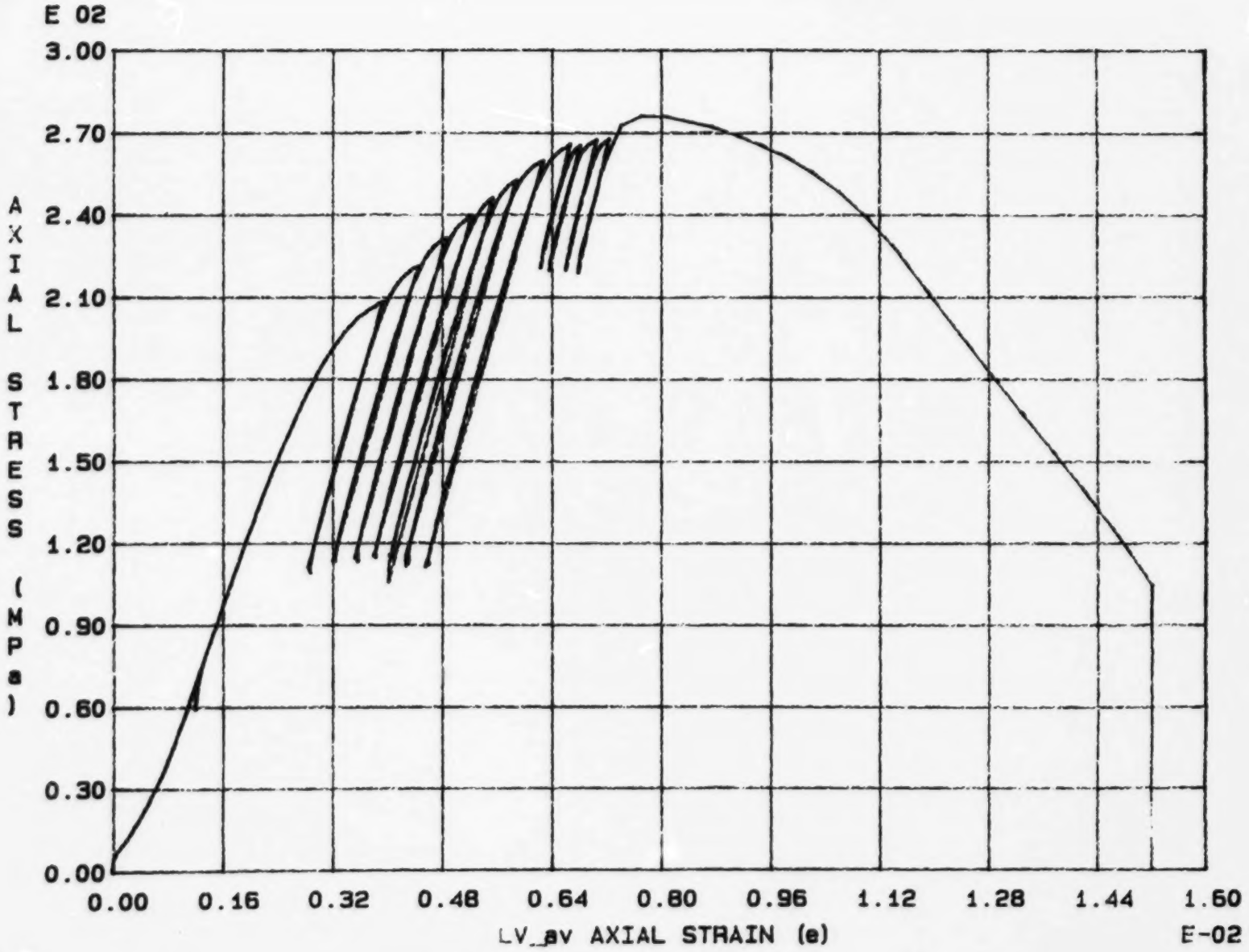


FIG.28 SPECIMEN 13

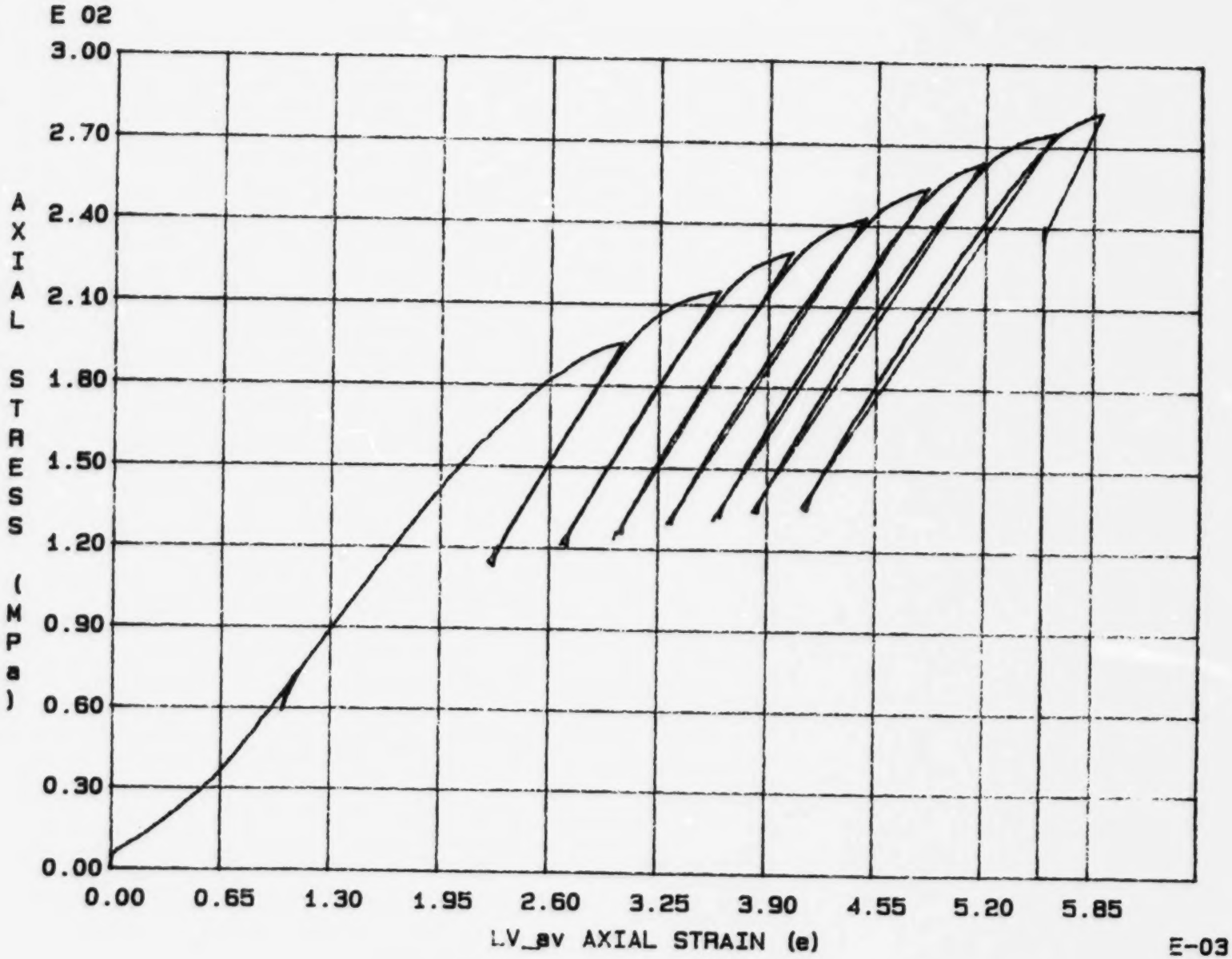


FIG.29 SPECIMEN 14

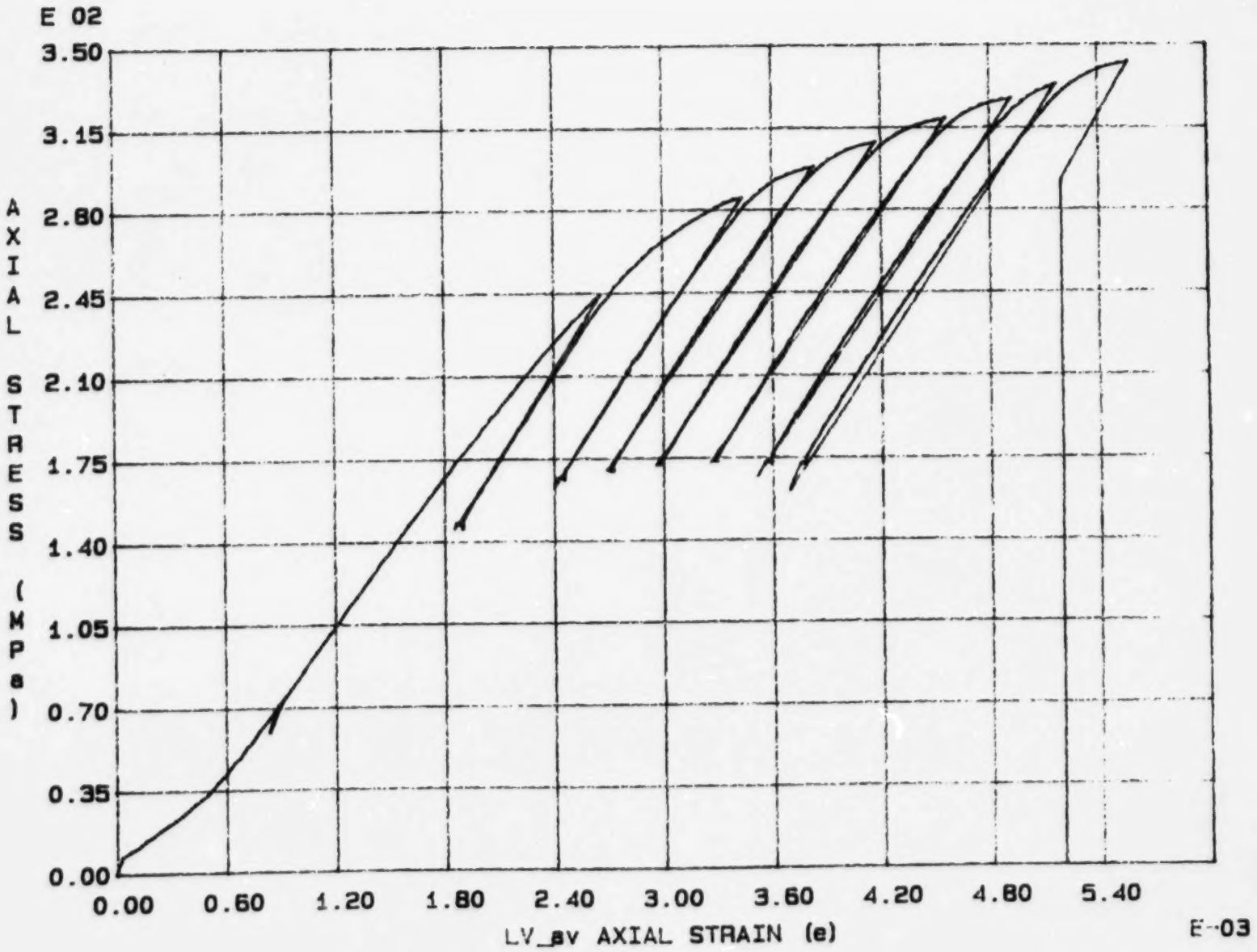


FIG.30 SPECIMEN 15

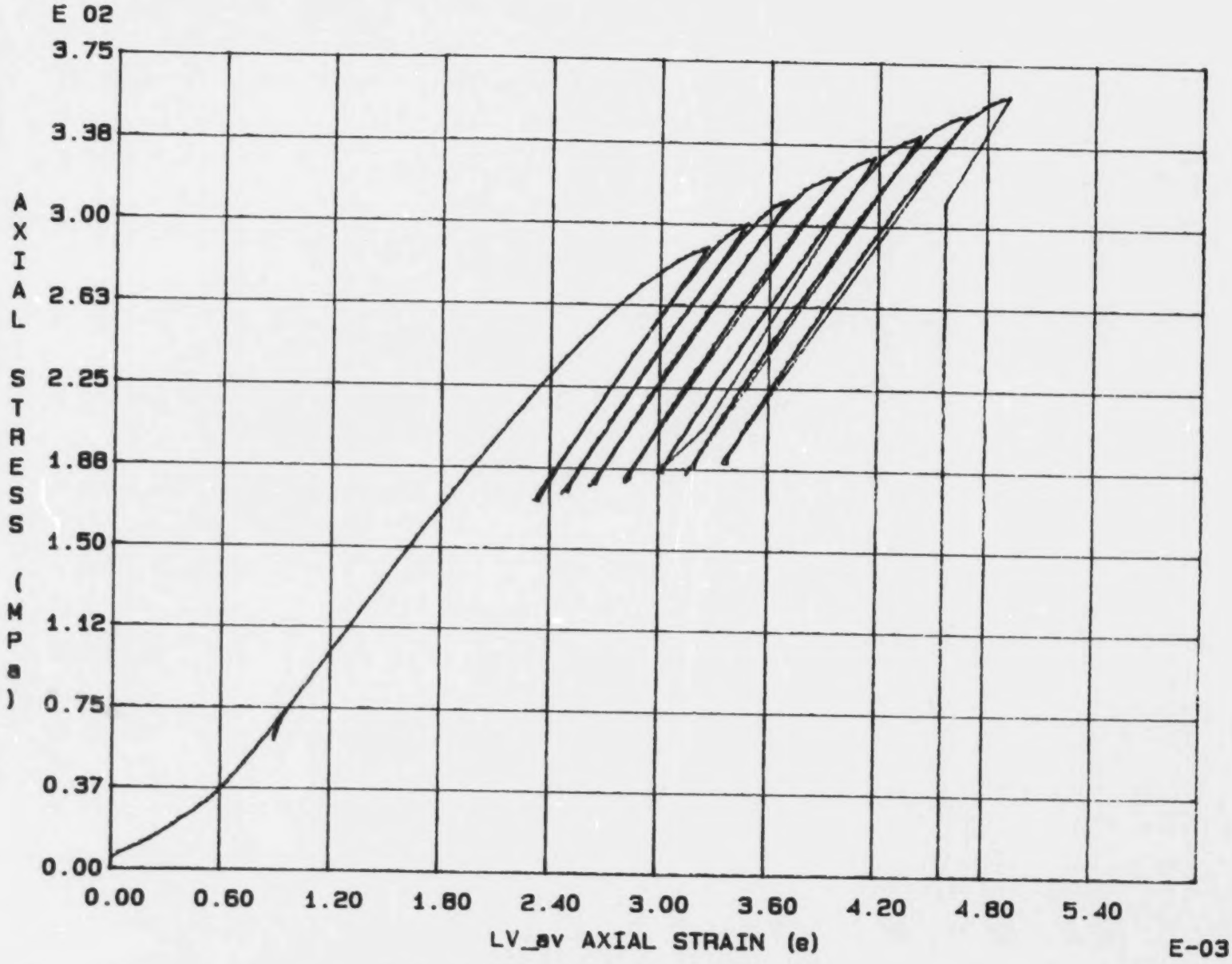


FIG.31 SPECIMEN 15A

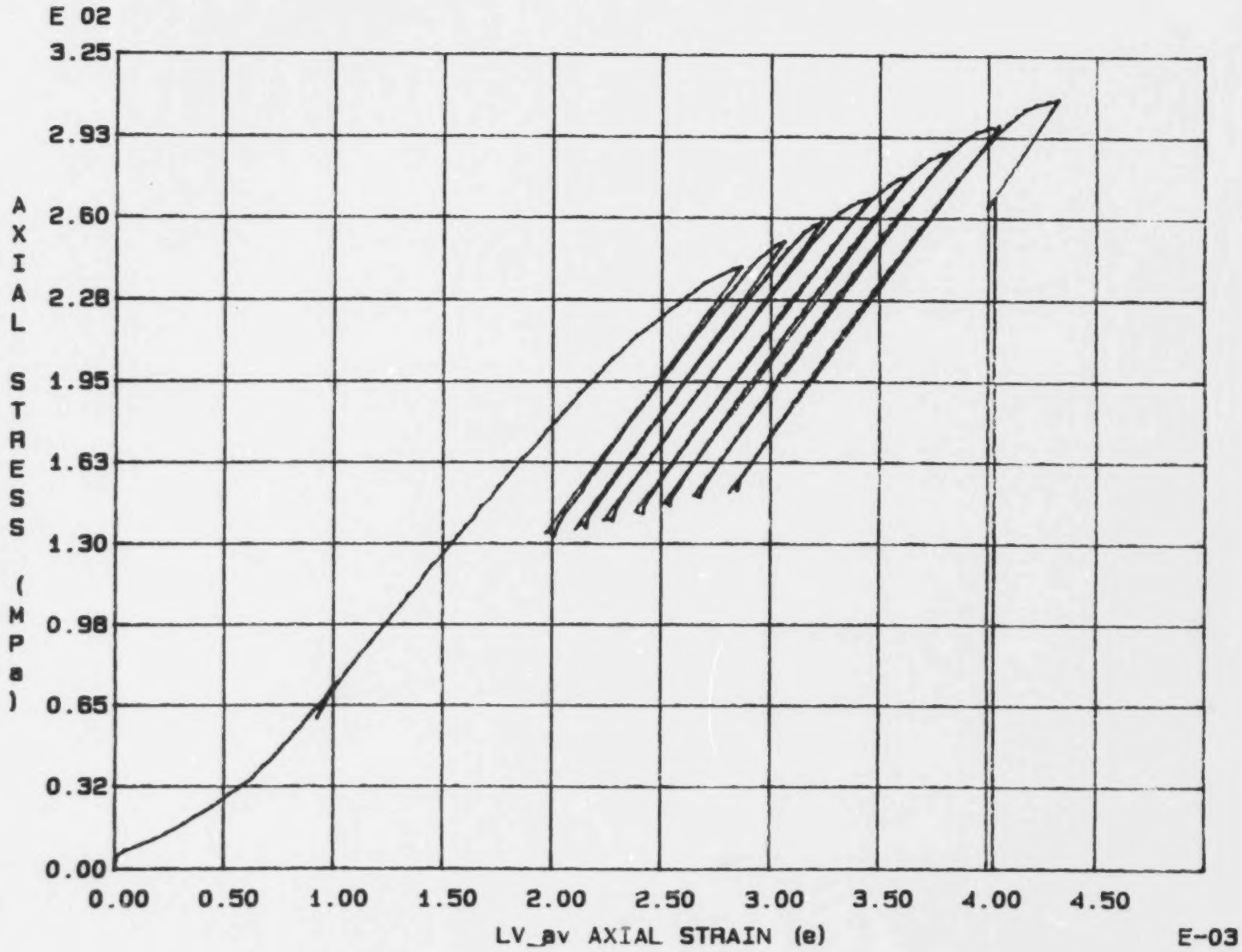


FIG.32 SPECIMEN 16

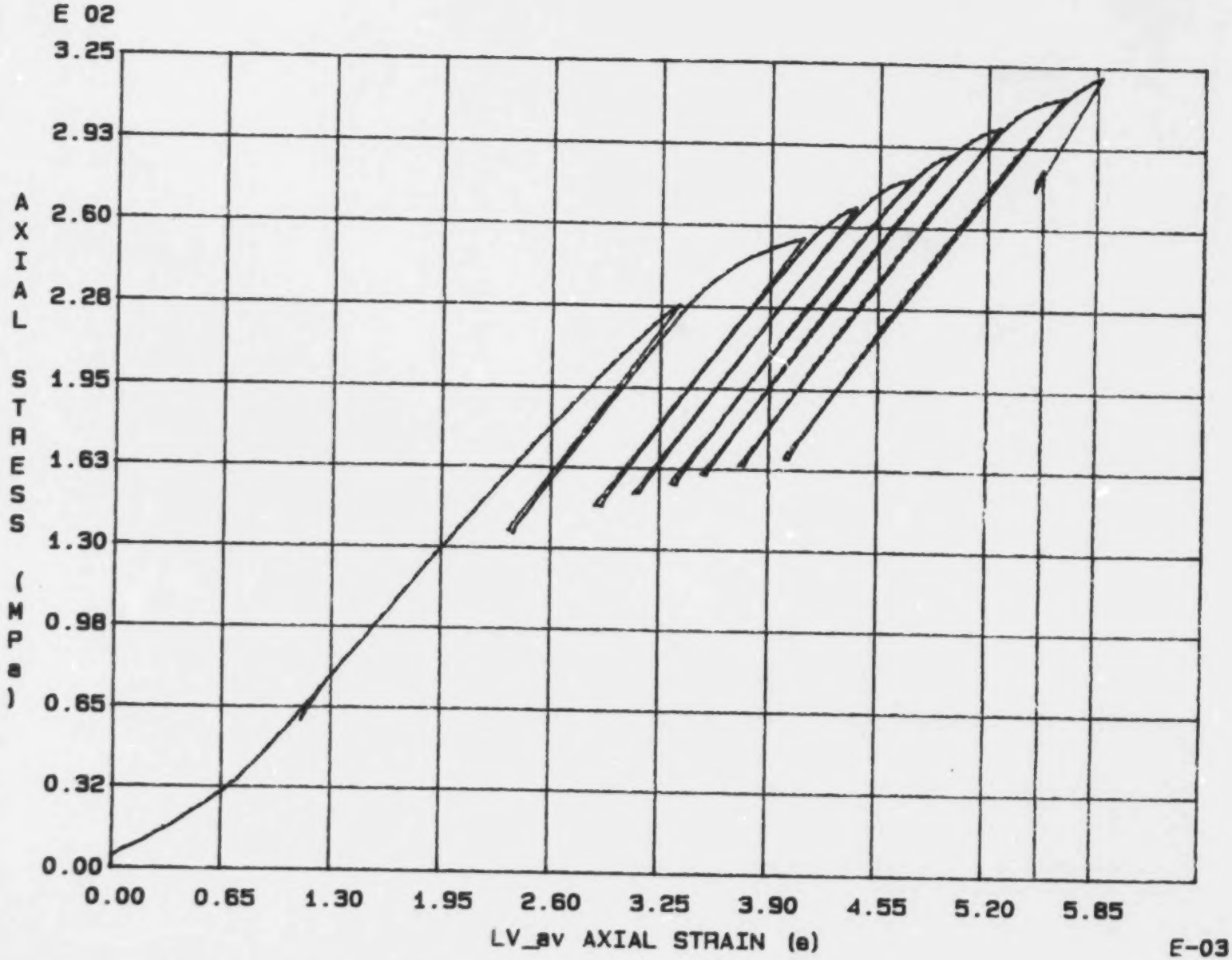


FIG.33 SPECIMEN 17

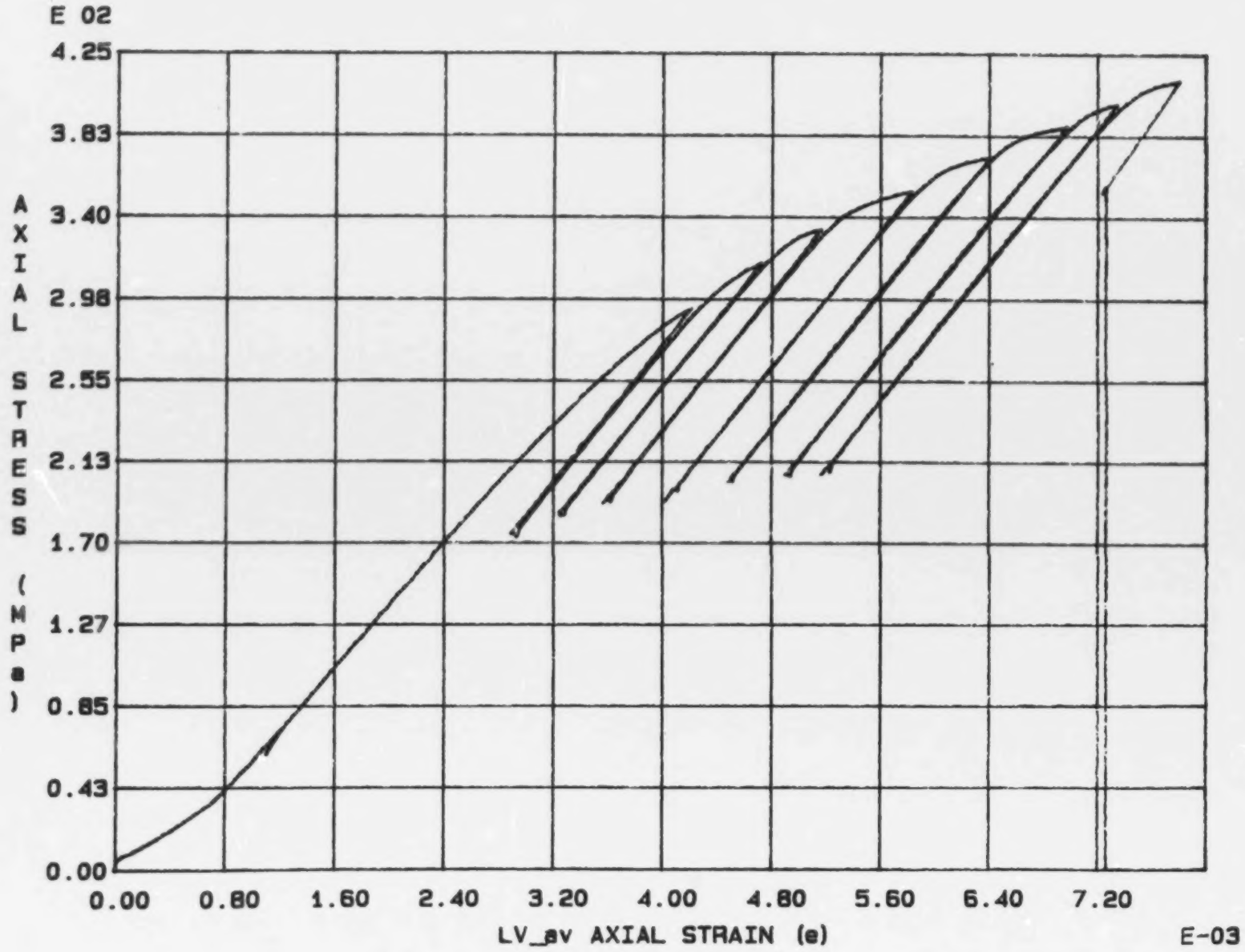


FIG.34 SPECIMEN 18

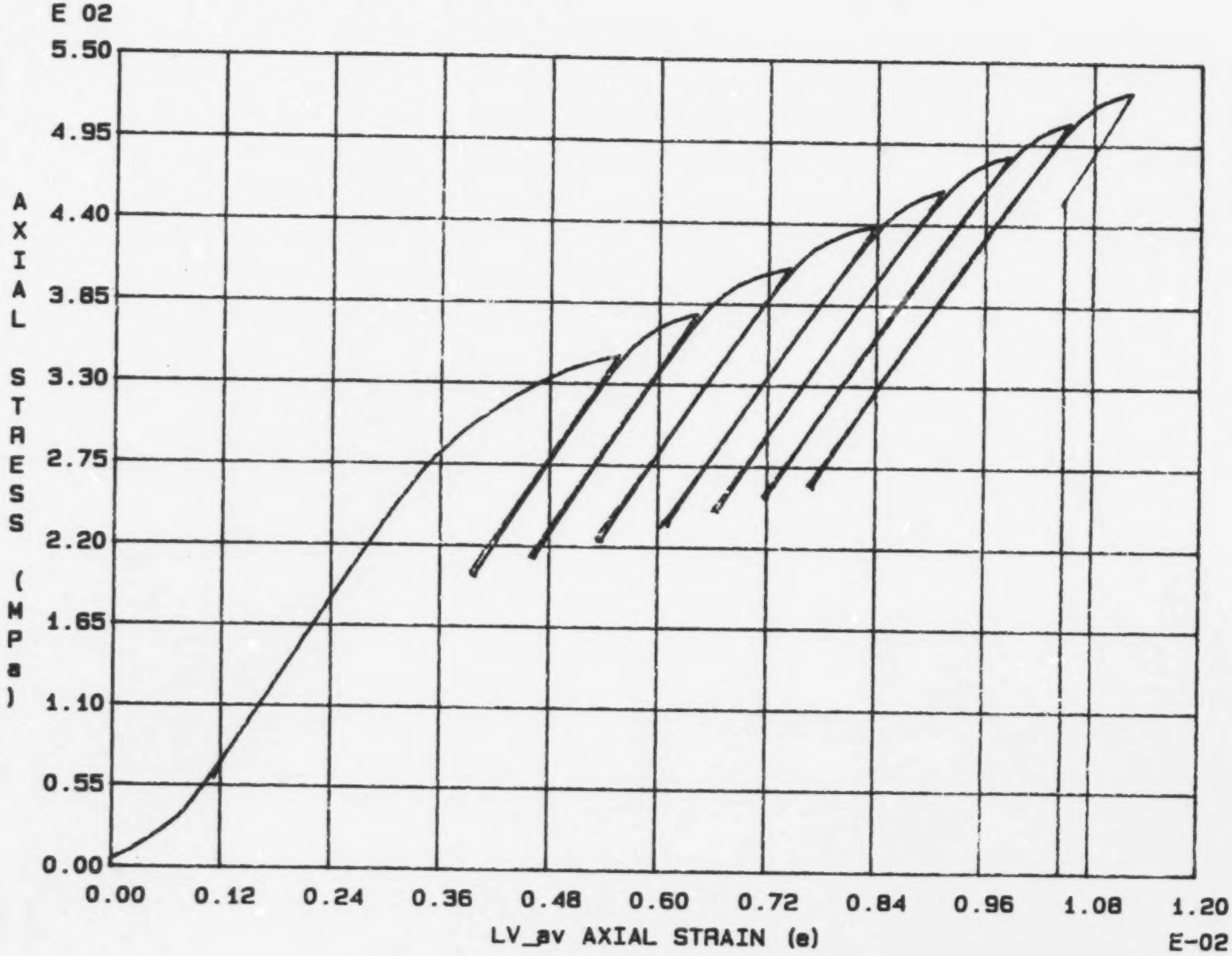


FIG.35 SPECIMEN 19

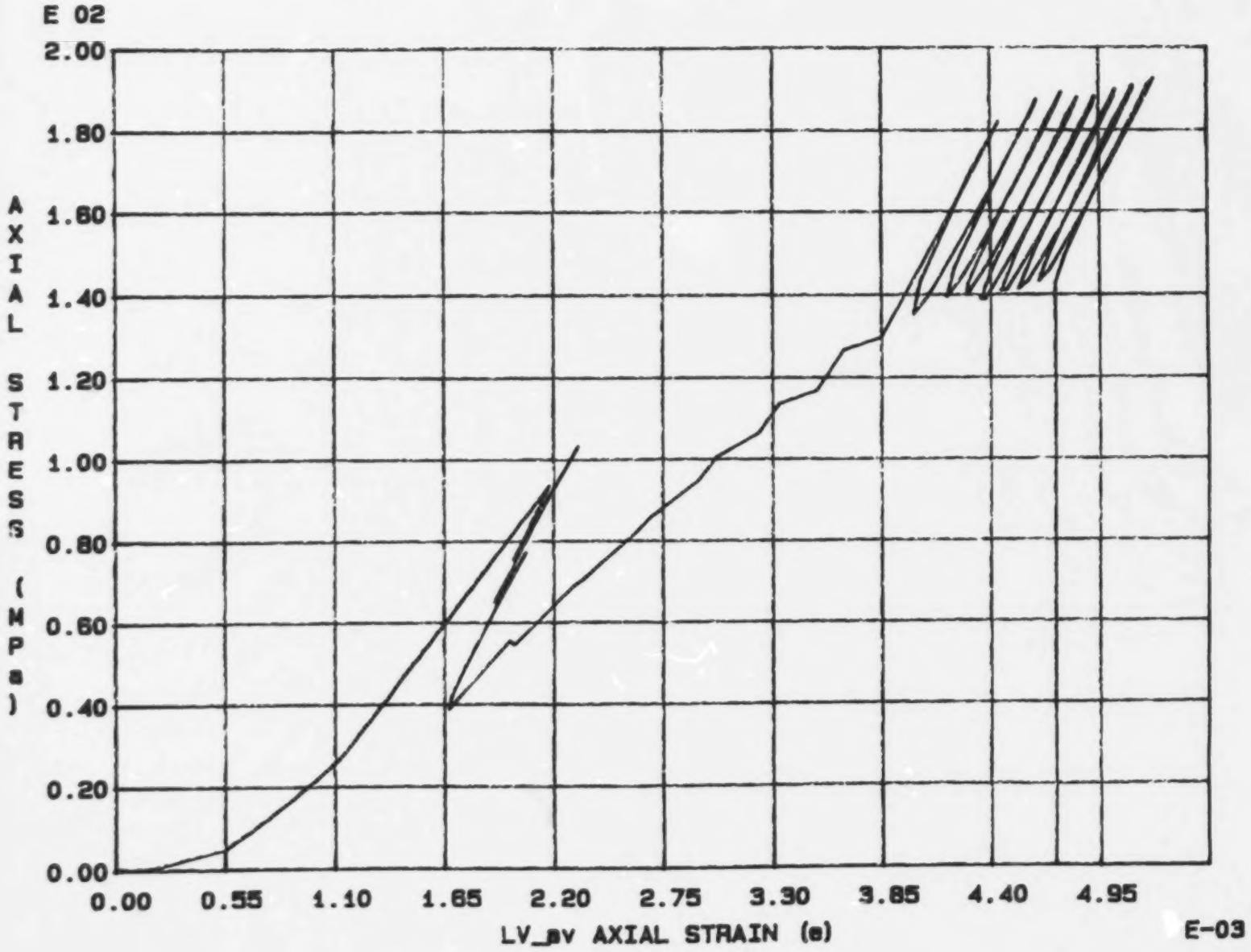


FIG.36 SPECIMEN 21

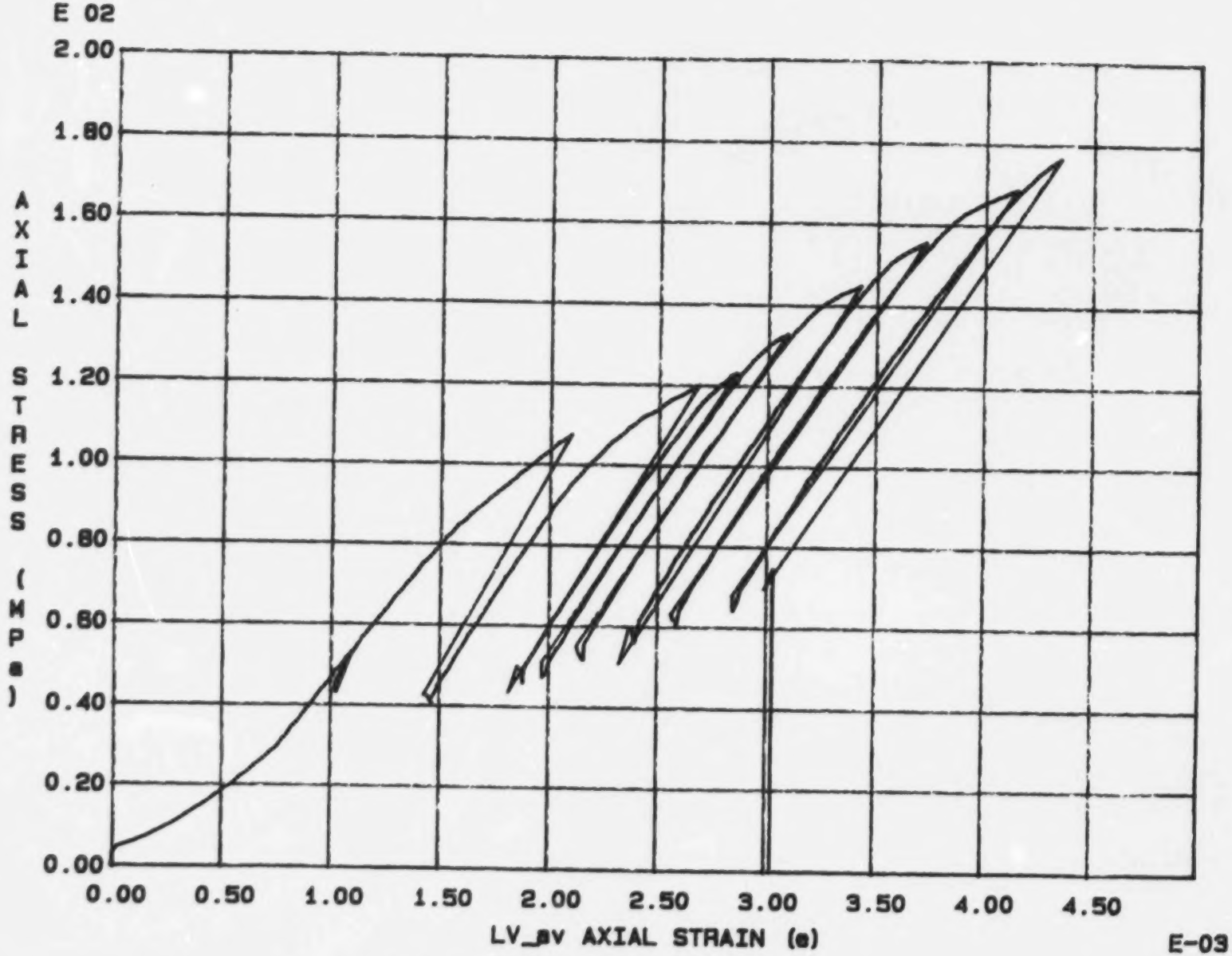


FIG.37 SPECIMEN 22

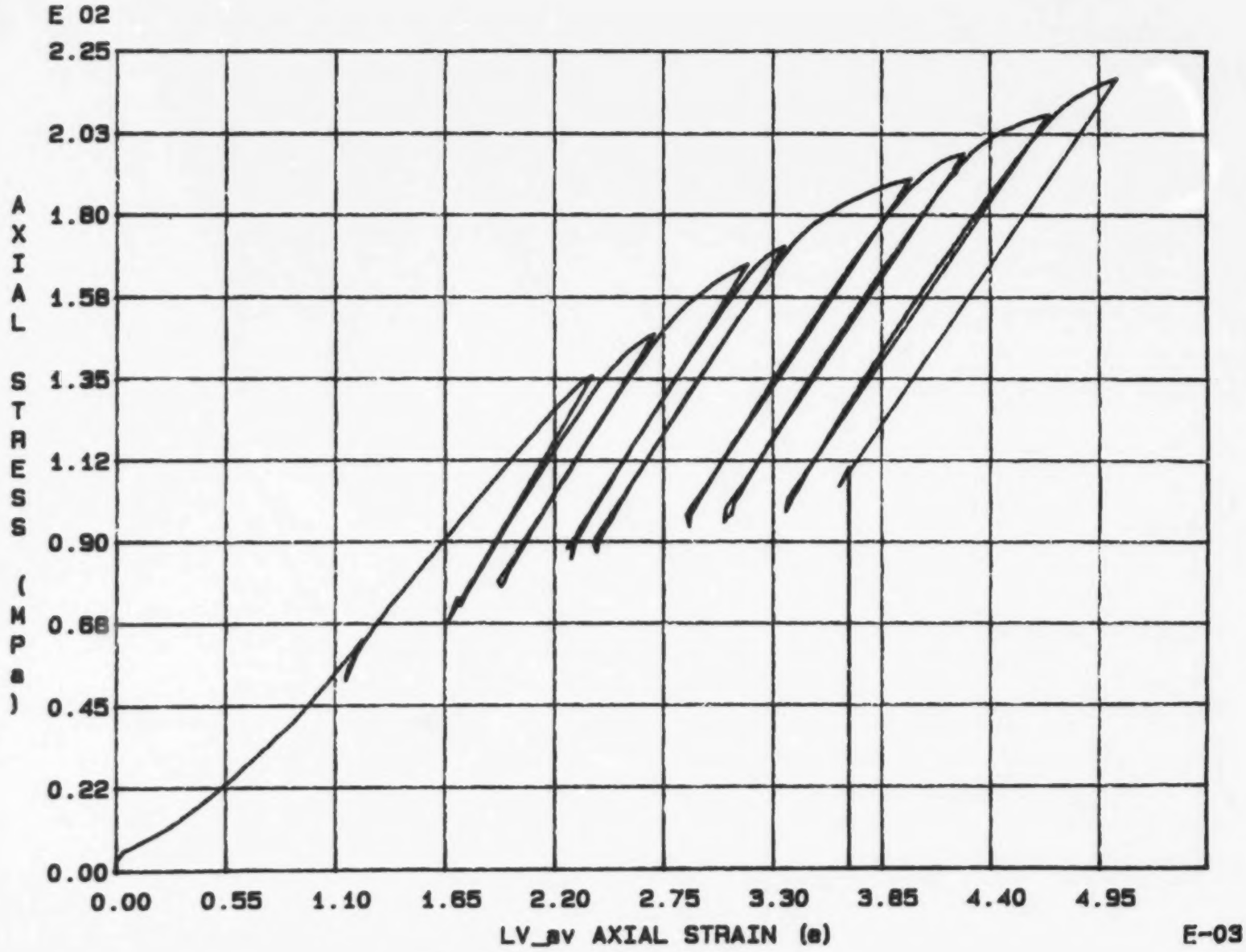


FIG.38 SPECIMEN 24

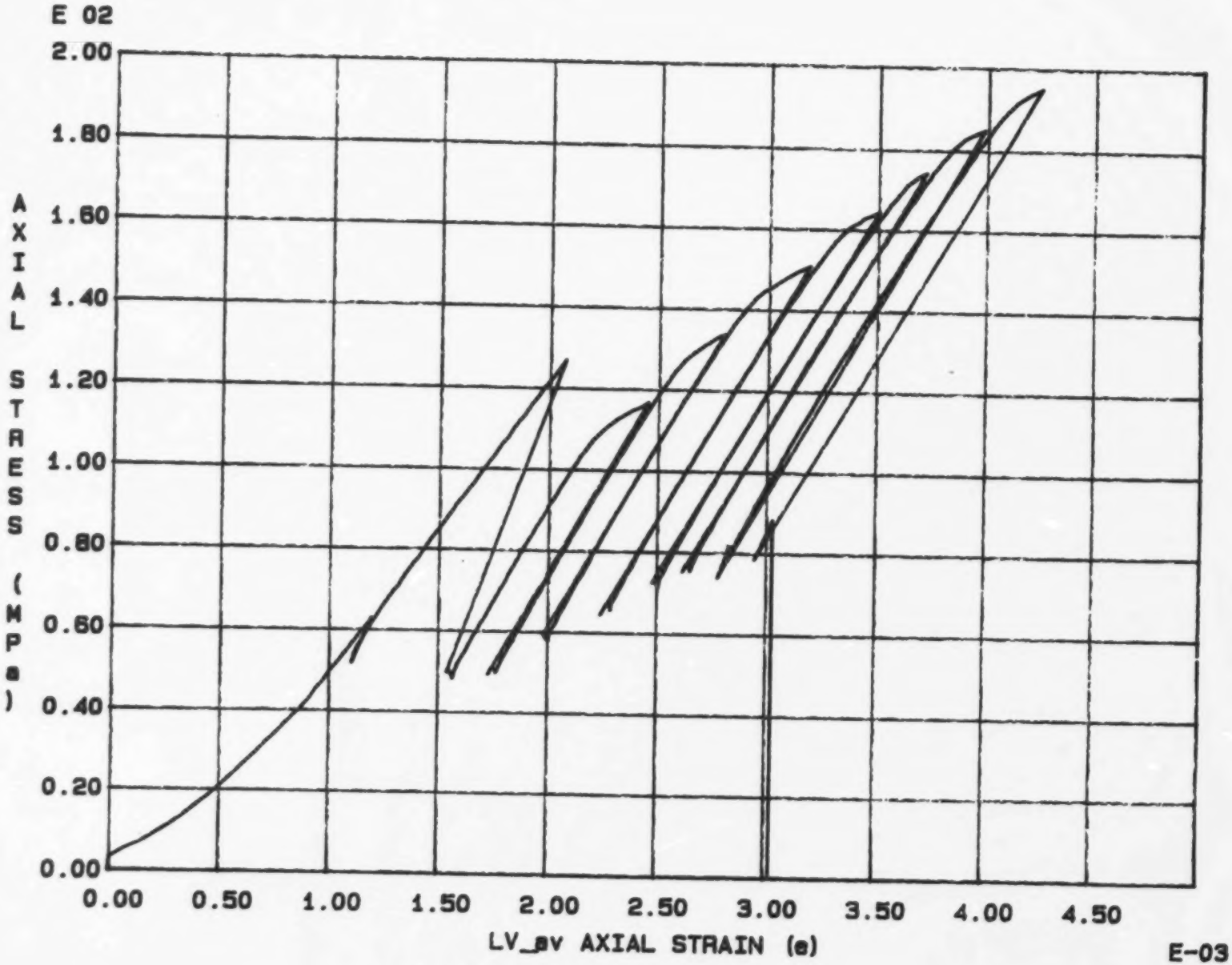


FIG.39 SPECIMEN 25

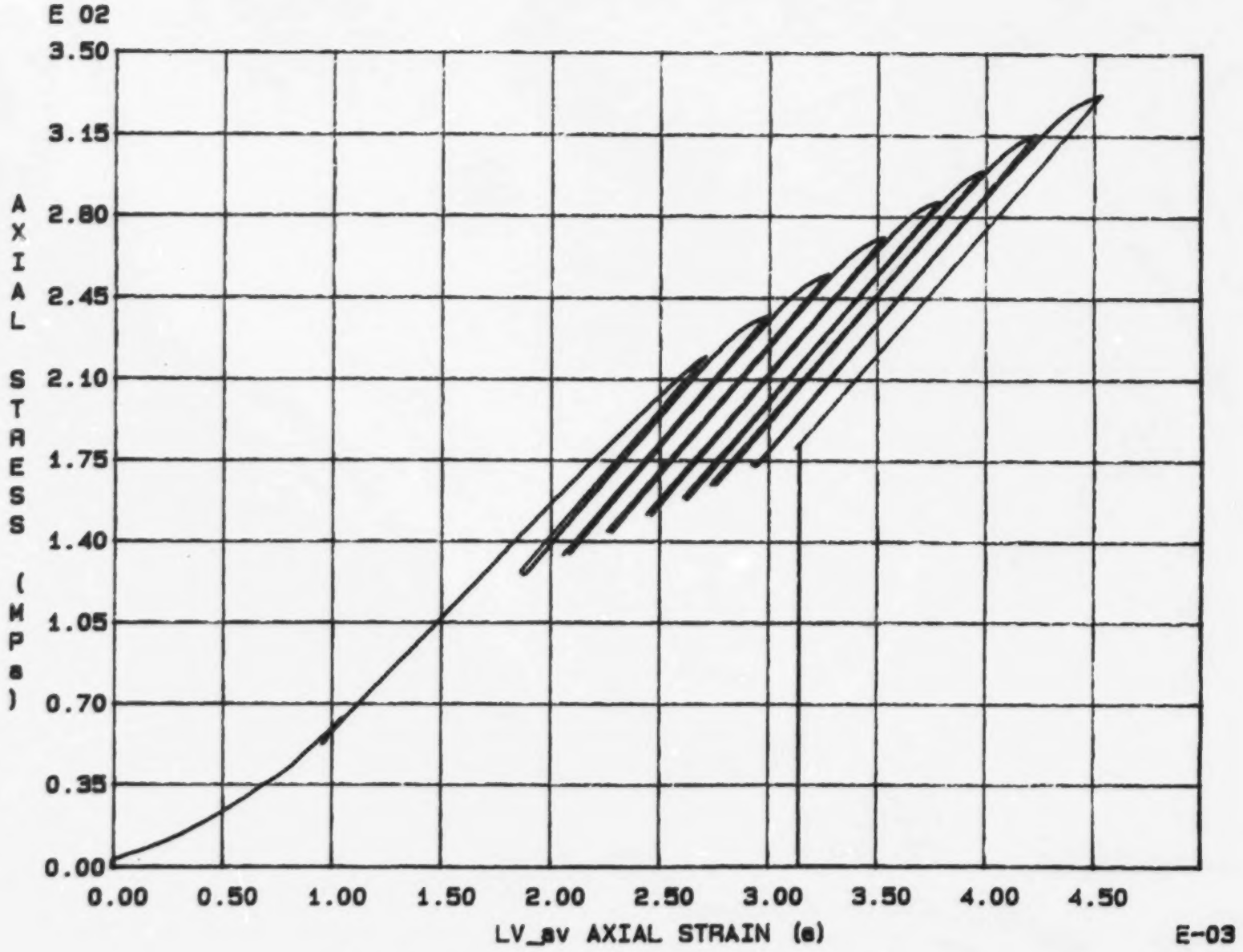


FIG.40 SPECIMEN 26

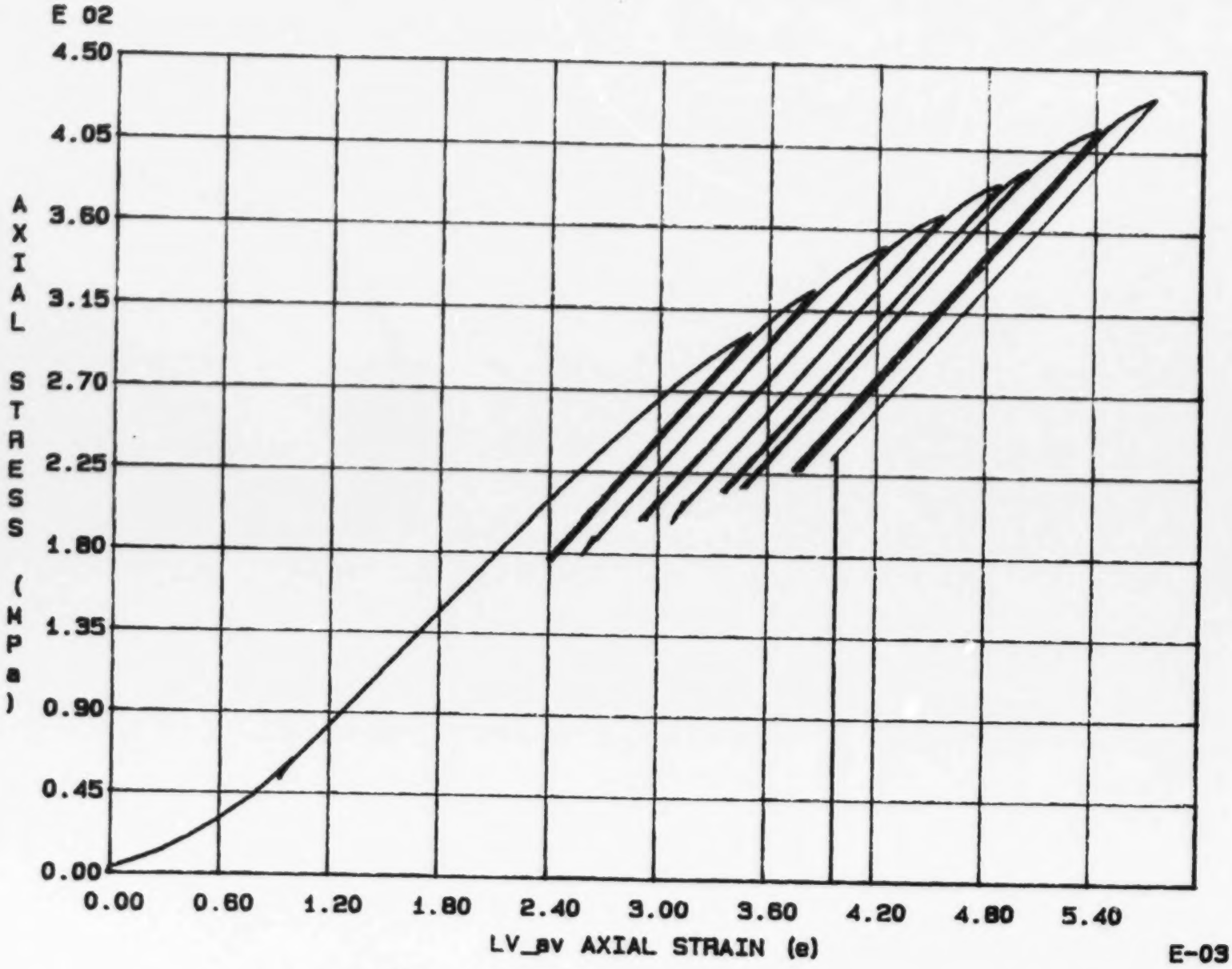


FIG.41 SPECIMEN 27

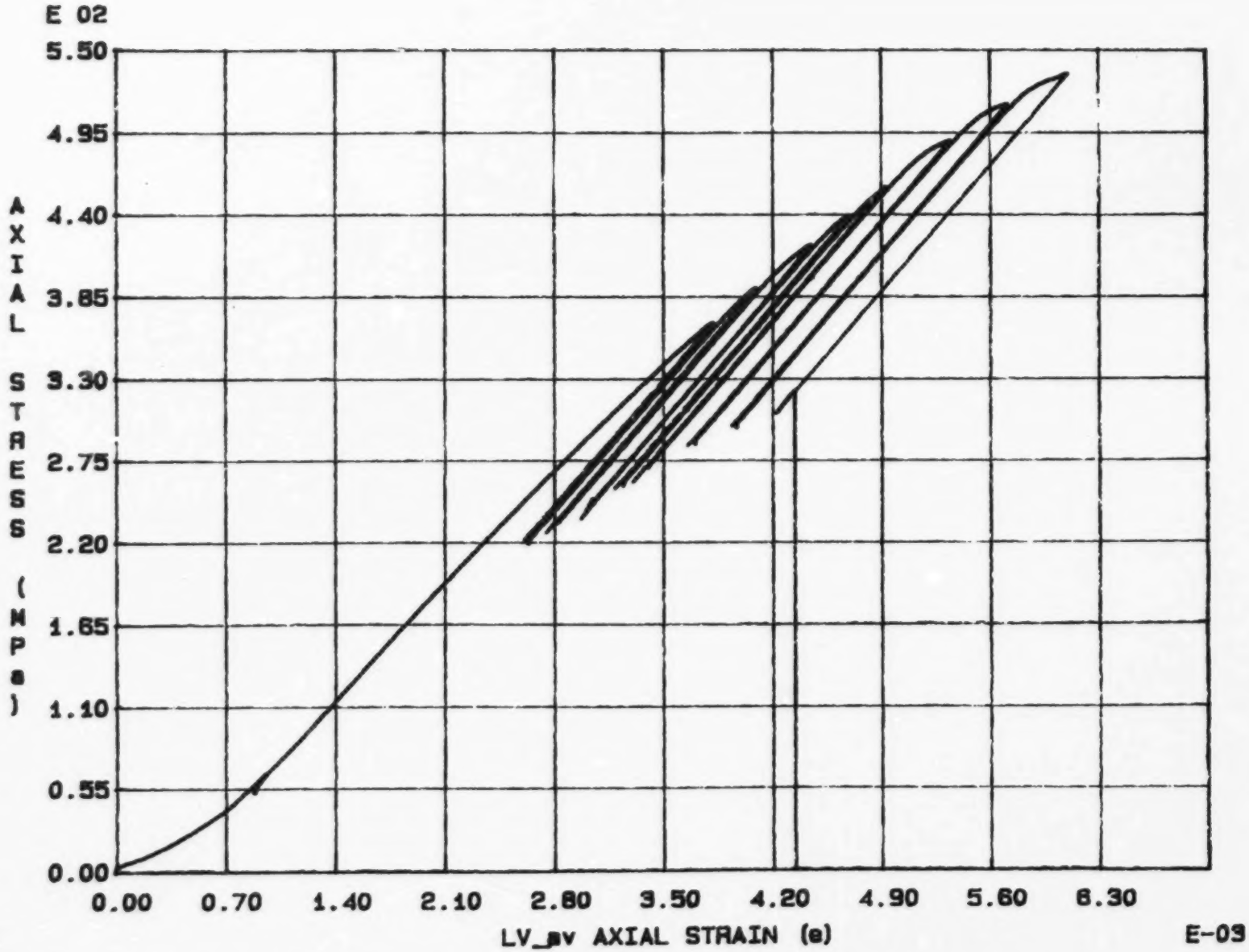


FIG.42 SPECIMEN 28

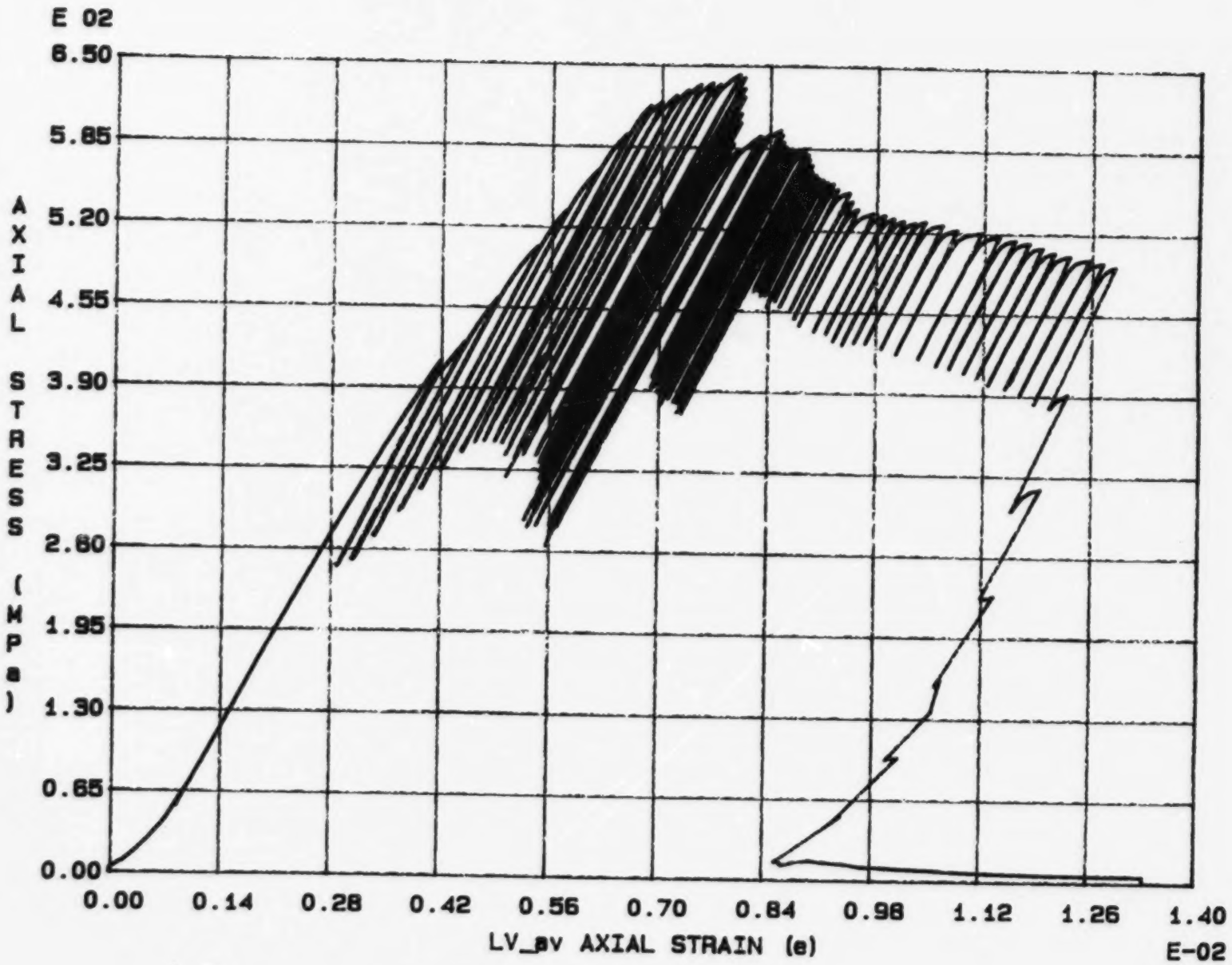


FIG.43 SPECIMEN 29

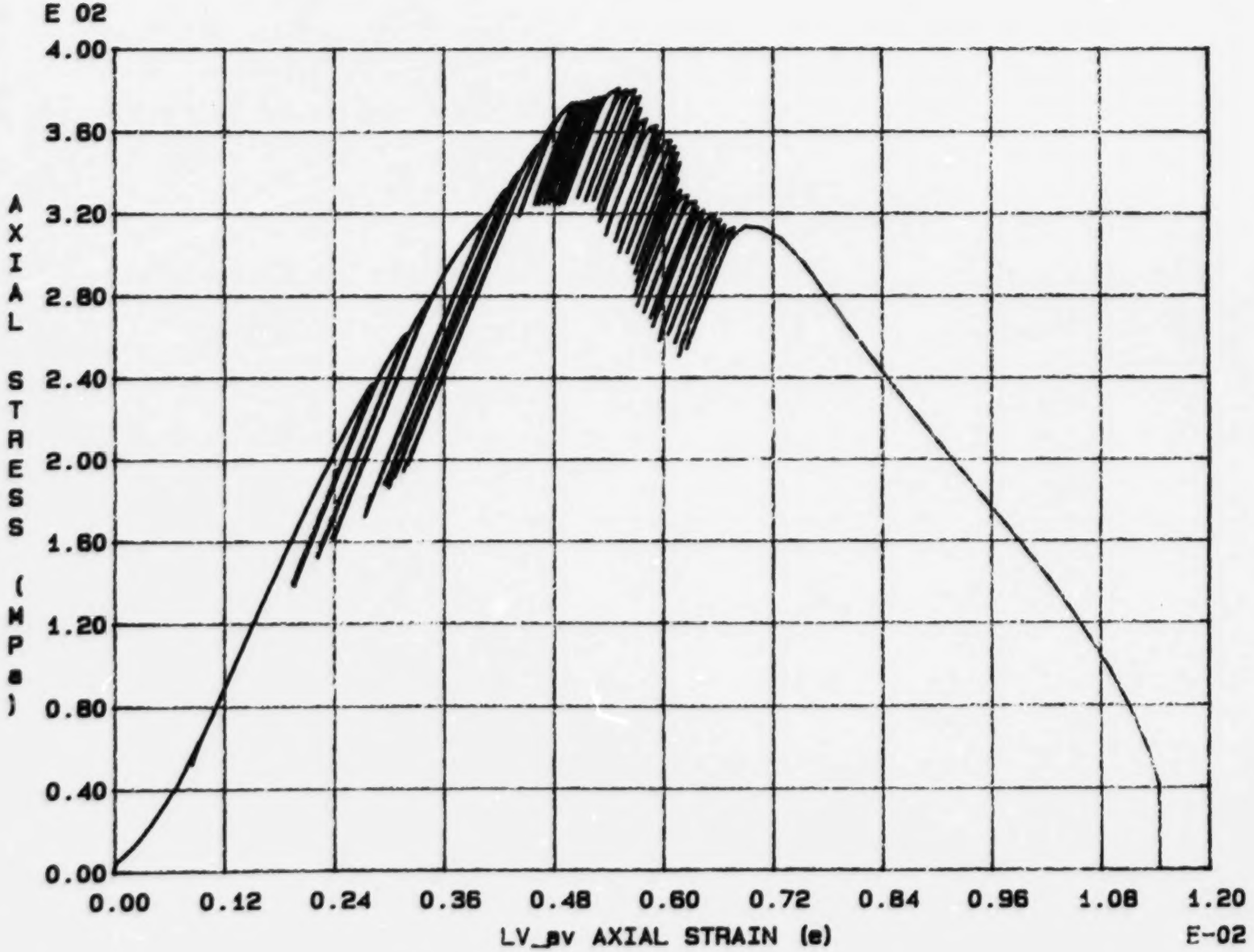


FIG.44 SPECIMEN 30

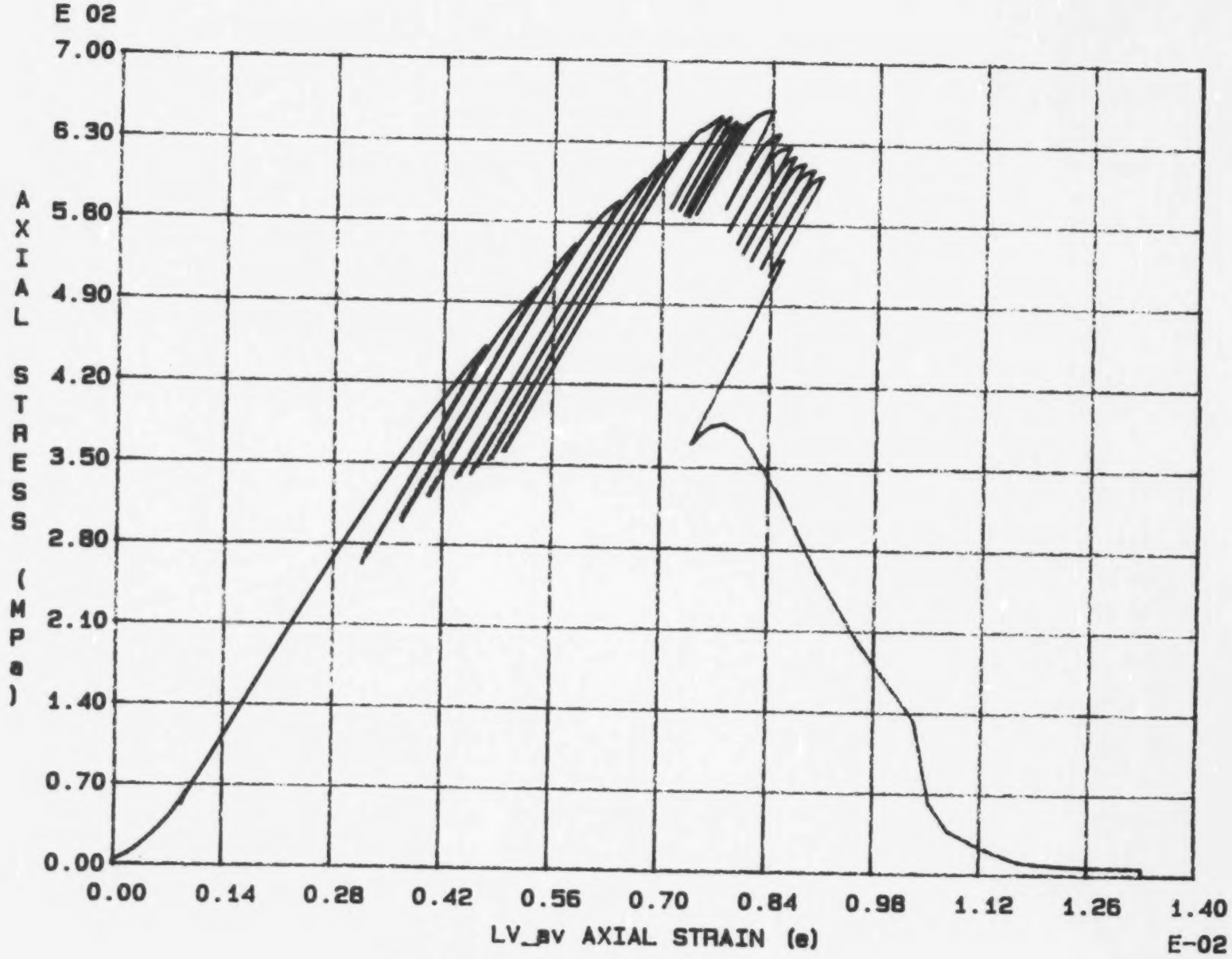


FIG.45 SPECIMEN 31

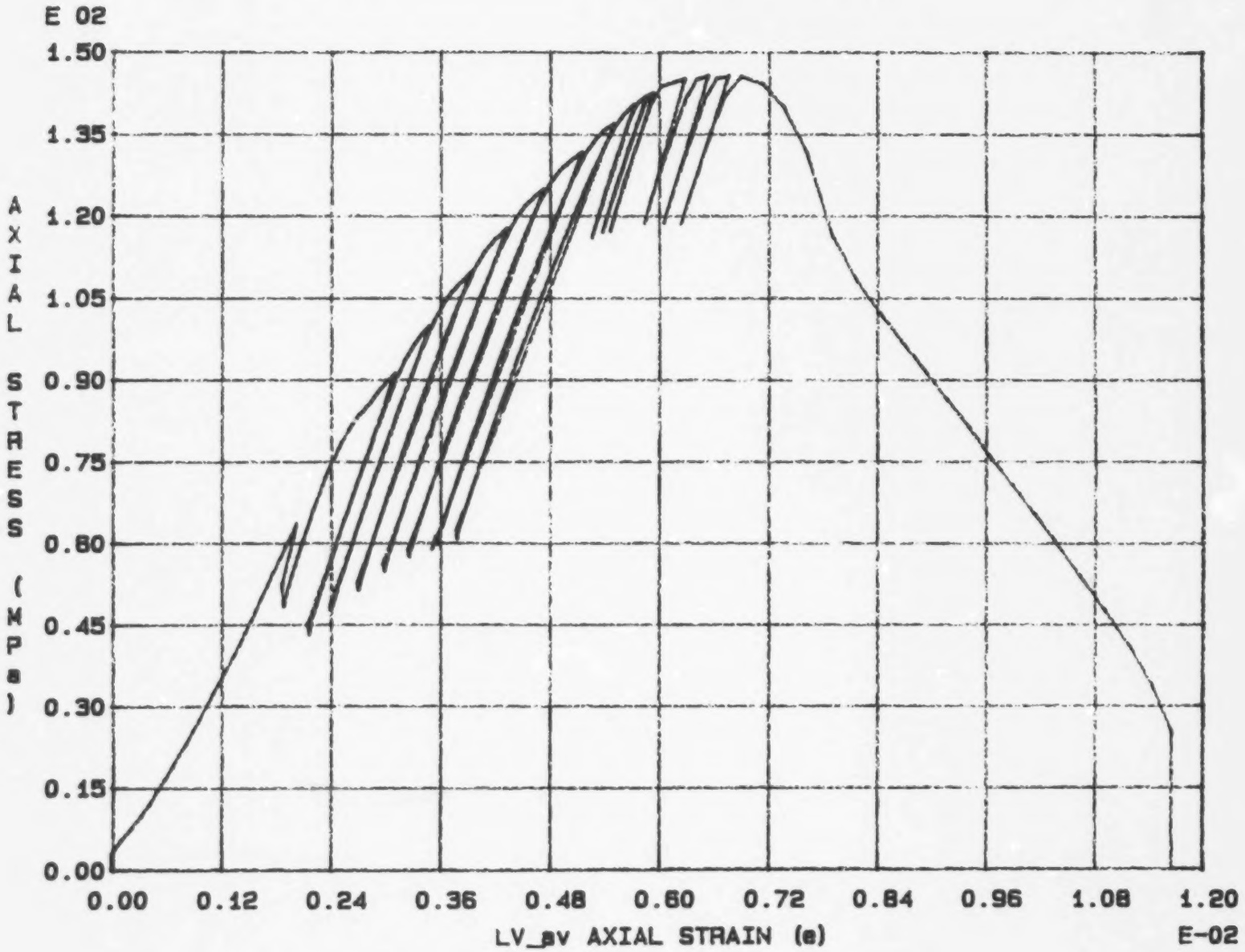


FIG.46 SPECIMEN 34

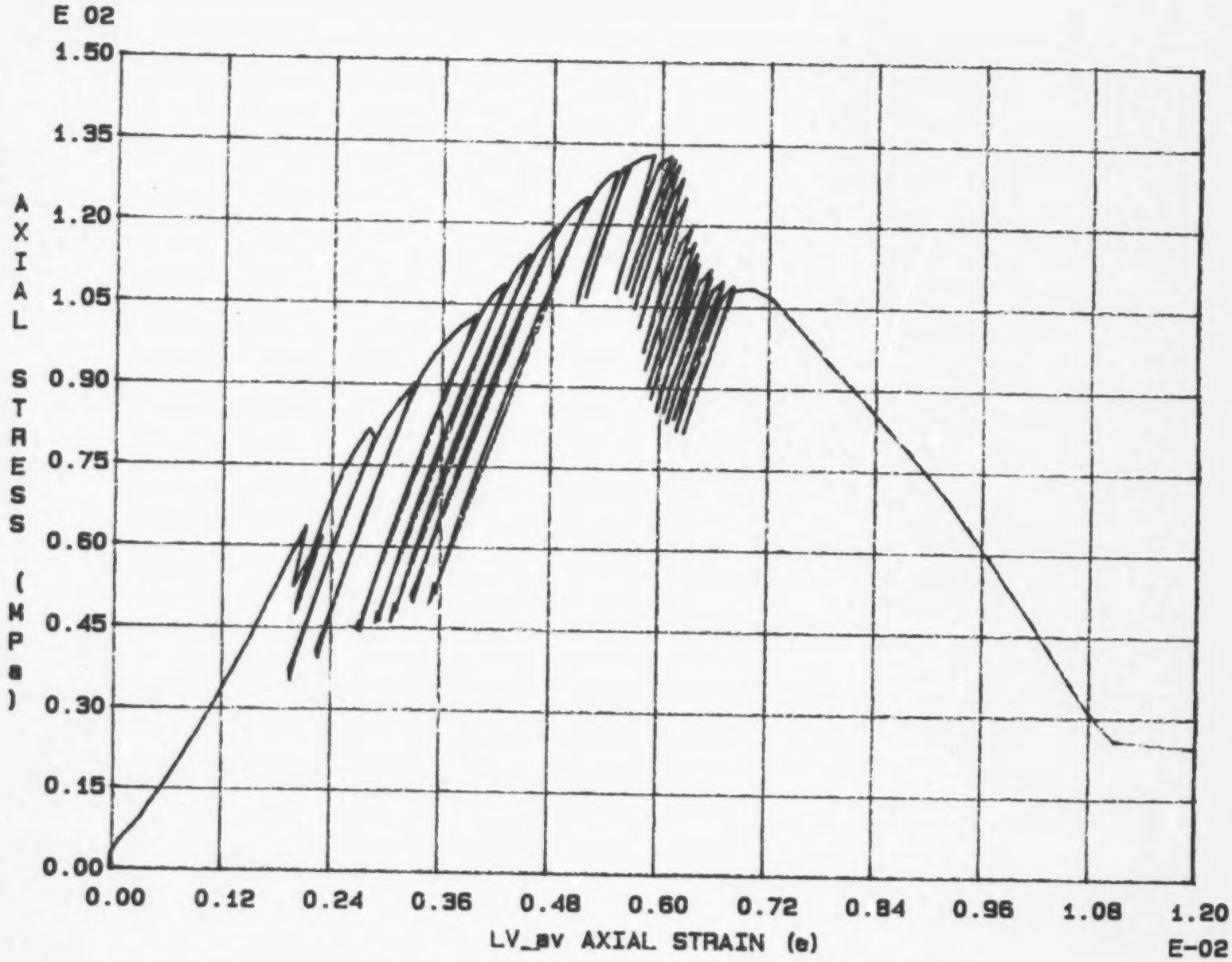


FIG.47 SPECIMEN 34A

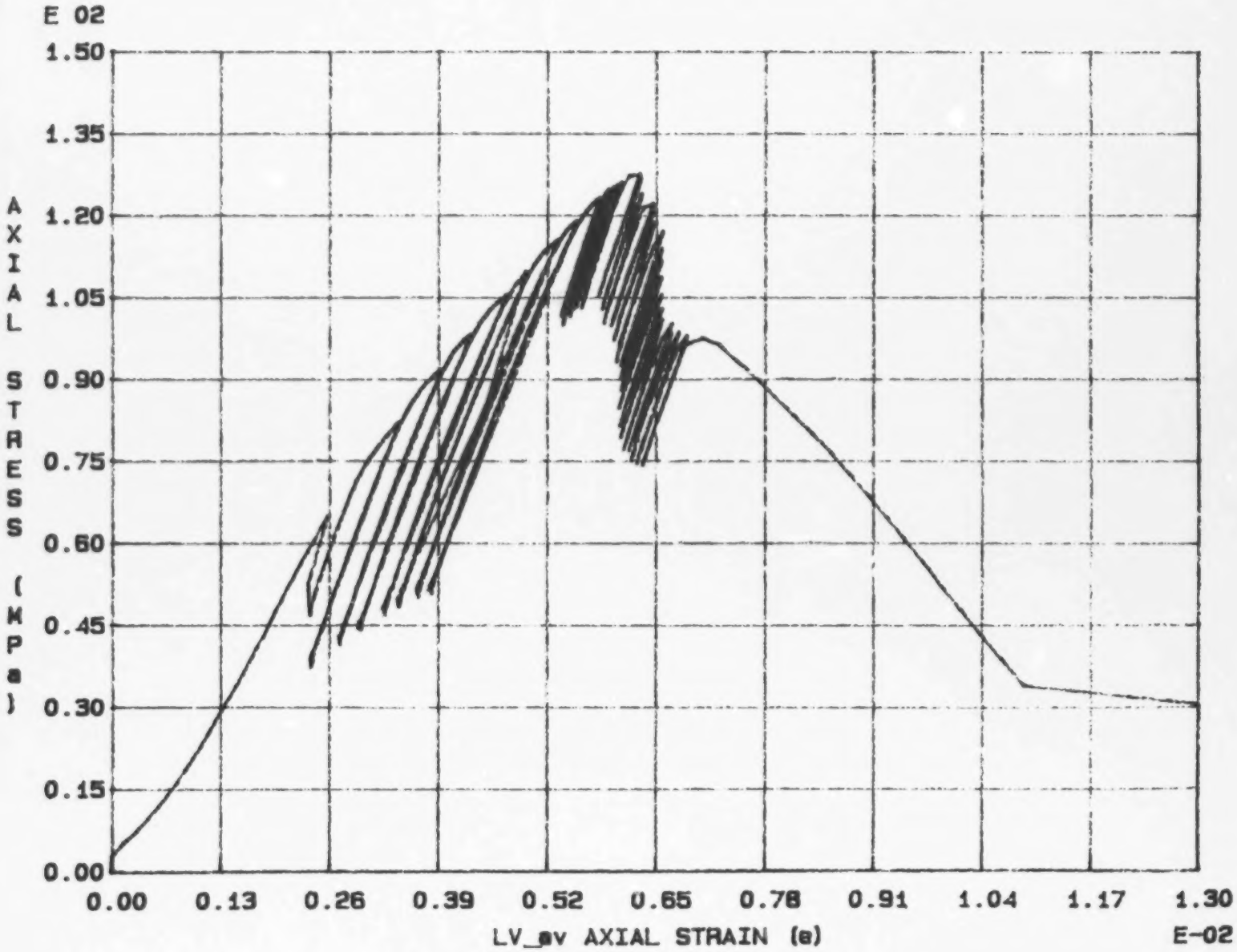


FIG.48 SPECIMEN 35

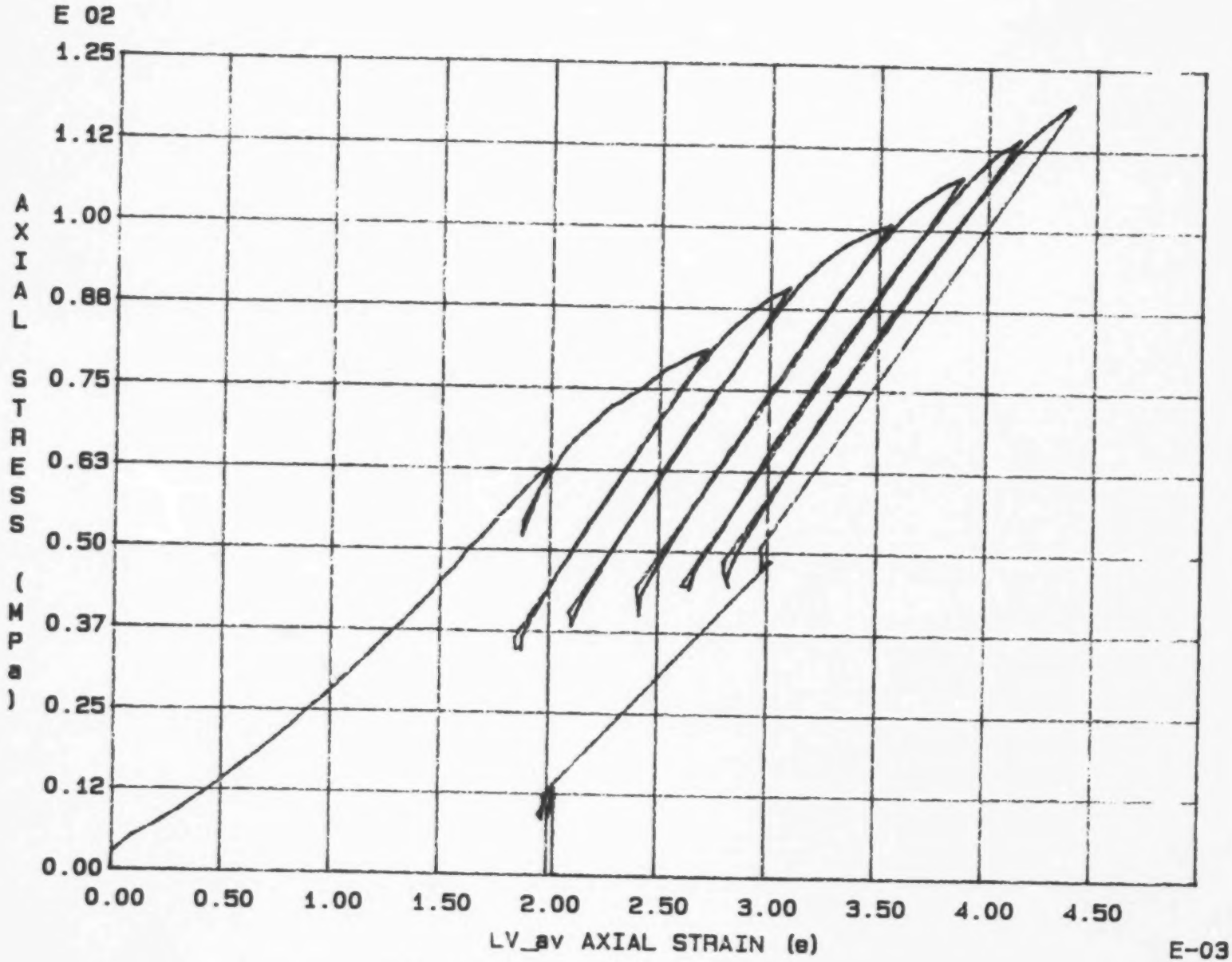


FIG.49 SPECIMEN 36

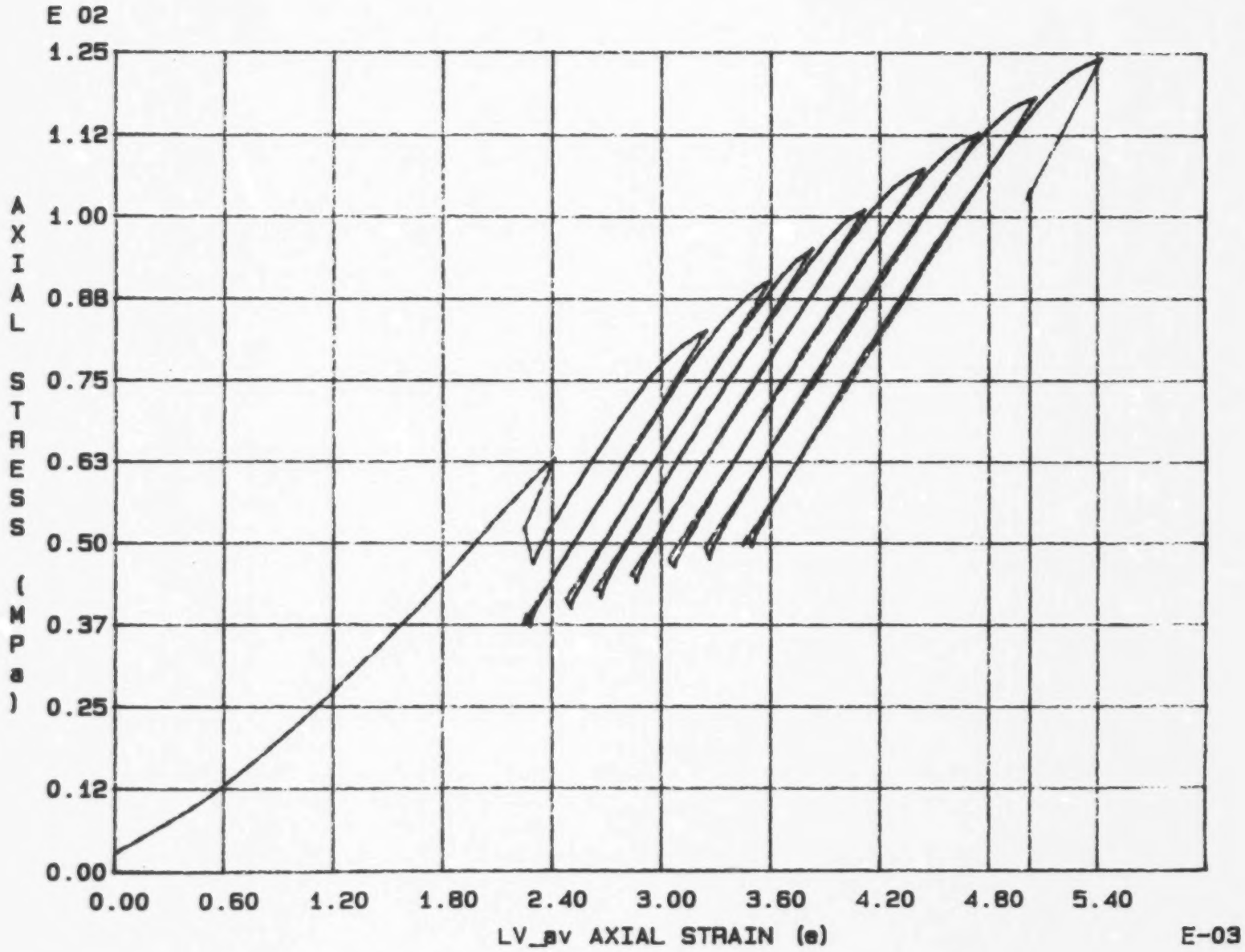


FIG.50 SPECIMEN 36A

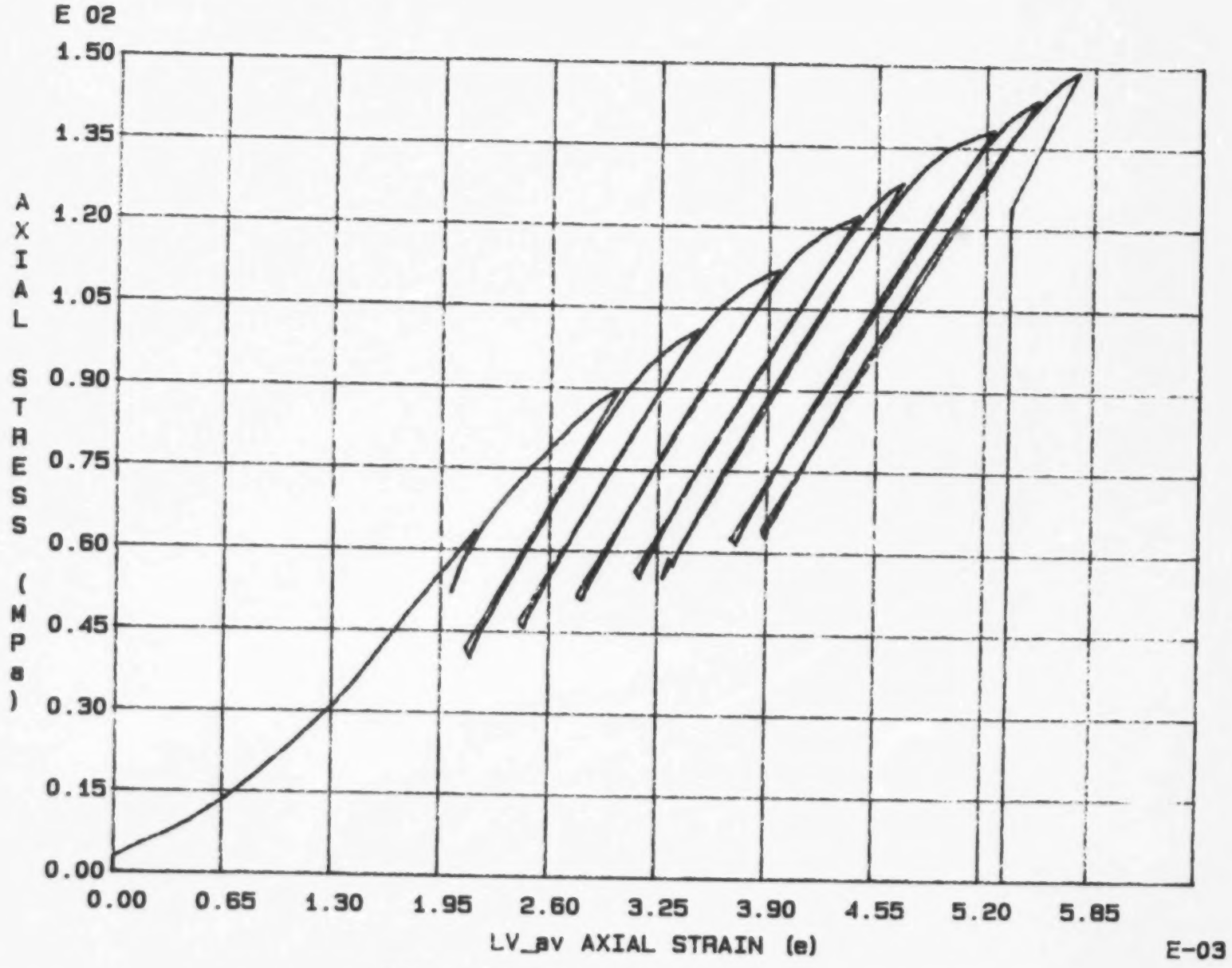


FIG.51 SPECIMEN 37

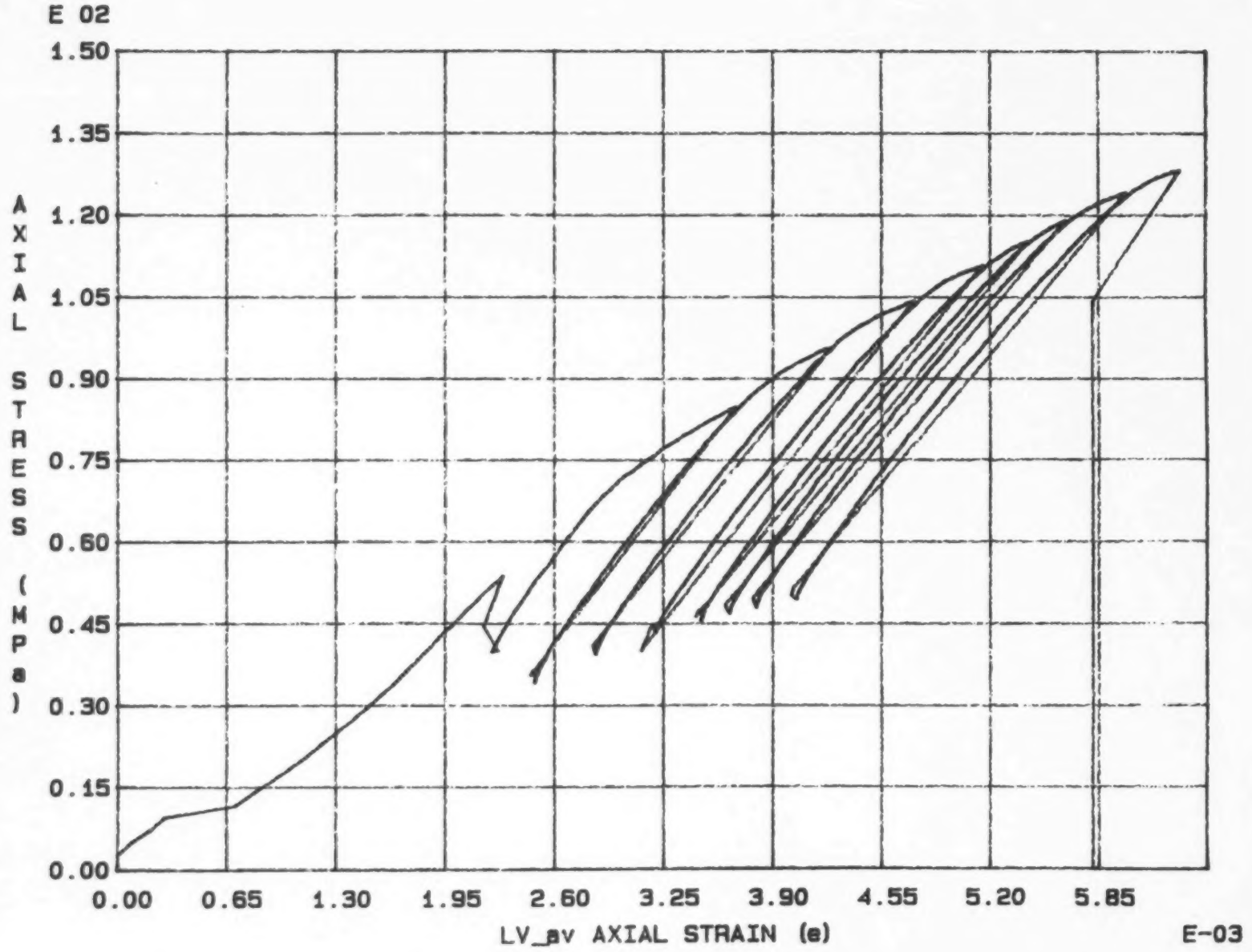


FIG.52 SPECIMEN 39

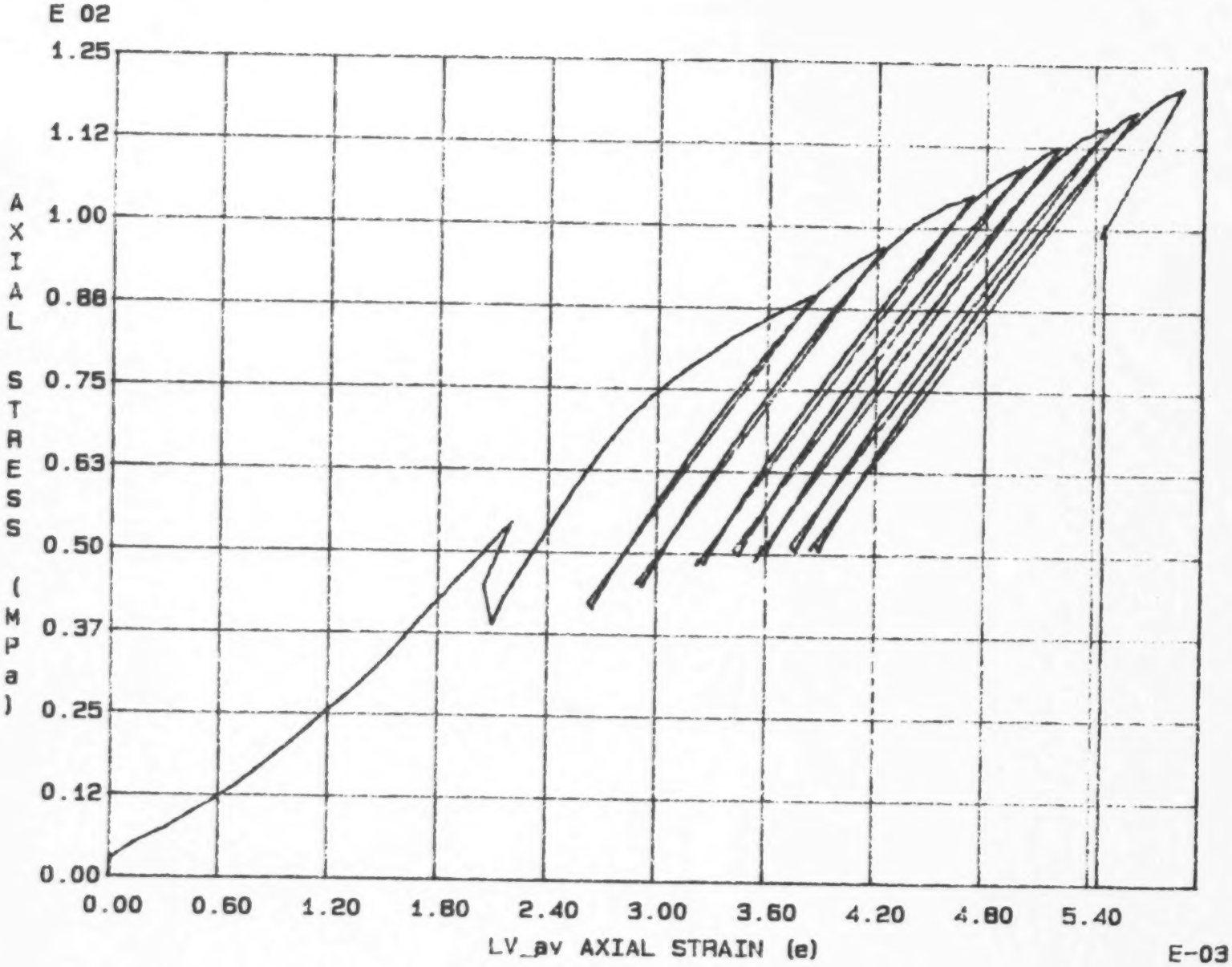


FIG.53 SPECIMEN 39A

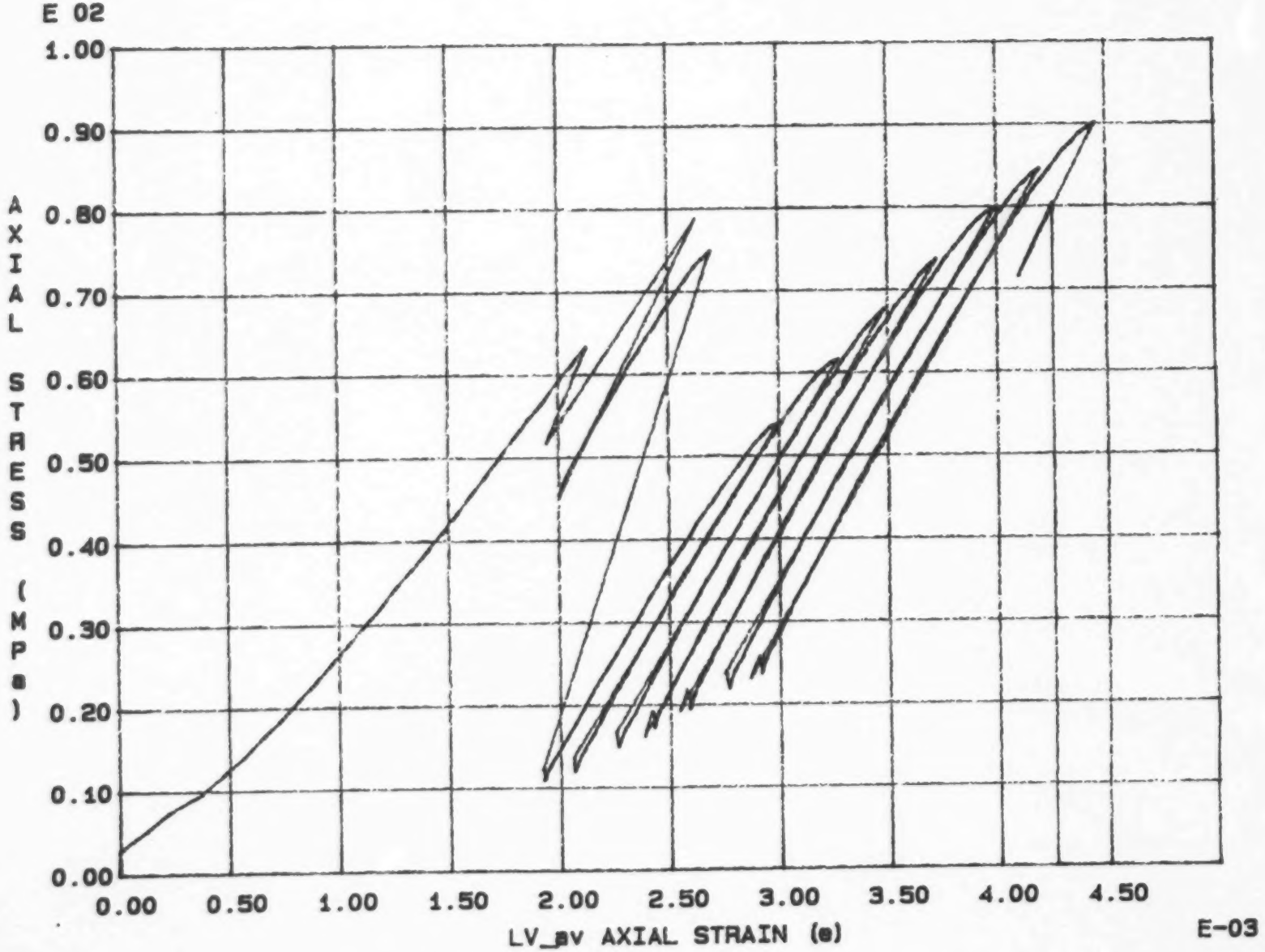


FIG.54 SPECIMEN 40

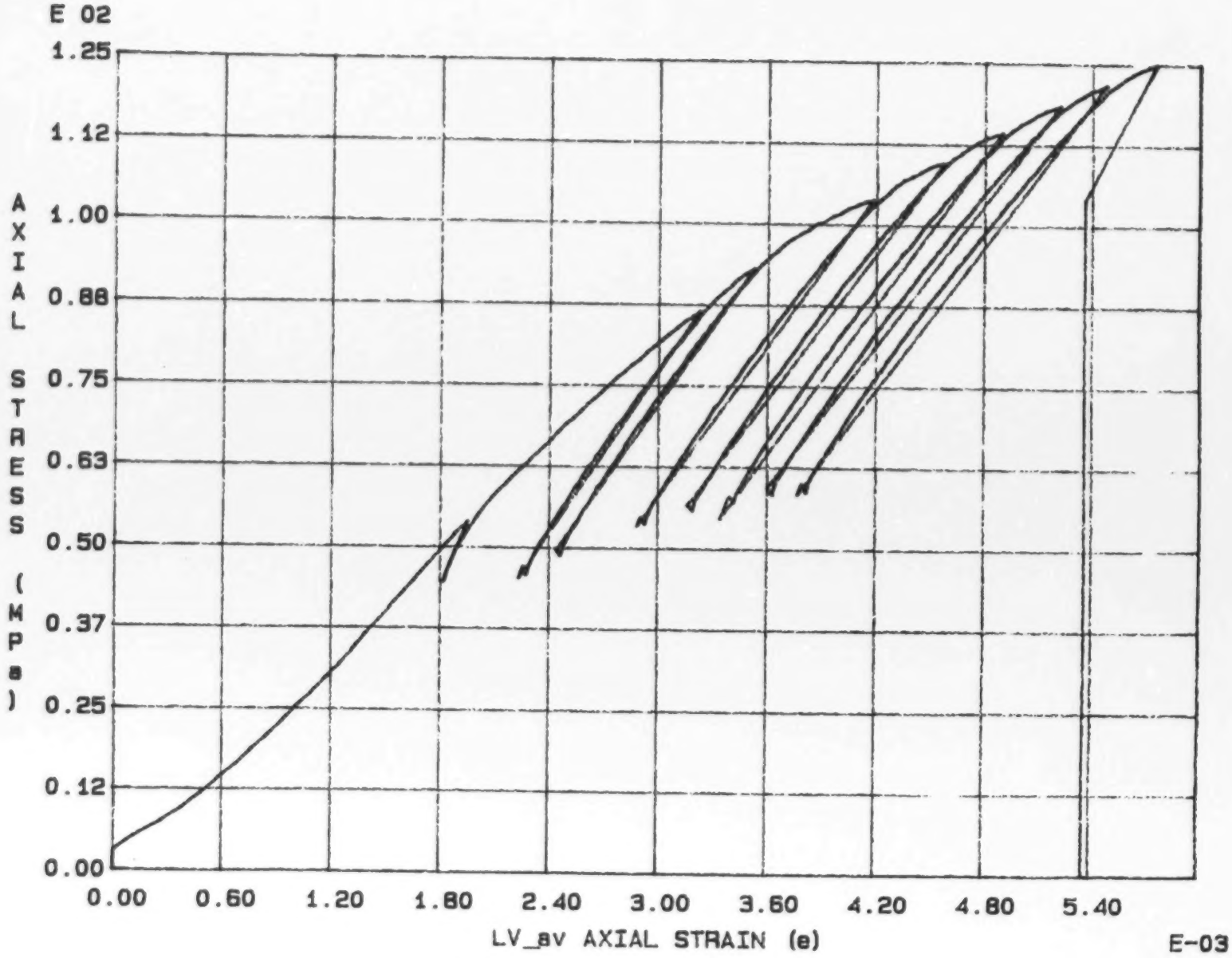


FIG.55 SPECIMEN 41